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REPORT

OF THE

Mass.

METROPOLITAN SEWERAGE COMMISSIONERS

UPON A

HIGH-LEVEL GRAVITY SEWER

FOR THE RELIEF OF THE

CHARLES AND NEPONSET RIVER VALLEYS.

COMPLIMENTS OF

METROPOLITAN SEWERAGE COMMISSIONERS.

HOSEA KINGMAN,
TILLY HAYNES,
GEORGE A. KIMBALL,
Commissioners.

WILLIAM M. BROWN, Jr.,
Chief Engineer and Superintendent.

HERBERT E. BRAYTON,
Clerk.

BOSTON:
WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
18 POST OFFICE SQUARE.
1899.

2 Dec. 1910
DEPARTMENT OF ARCHITECTURE,
HARVARD UNIVERSITY.
Gift of the
Metropolitan Water & Sewerage Board

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Commonwealth of Massachusetts.

REPORT

OF THE

METROPOLITAN SEWERAGE COMMISSIONERS

UPON A

HIGH-LEVEL GRAVITY SEWER

FOR THE RELIEF OF THE

CHARLES AND NEPONSET RIVER VALLEYS.

To the General Court of Massachusetts.

The resolve of the General Court under which the Board of Metropolitan Sewerage Commissioners has made investigations into the sanitary needs of the Charles and Neponset River valleys and has prepared designs for a high-level gravity sewer for the relief of the south metropolitan sewerage district is as follows: —

[Resolves of 1898, Chapter 4.]

RESOLVE RELATIVE TO A HIGH-LEVEL SEWER FOR THE RELIEF OF THE CHARLES AND NEPONSET RIVER VALLEYS.

Resolved, That the board of metropolitan sewerage commissioners is hereby authorized and directed to consider and report upon a high-level system of sewerage for the Charles and Neponset river valleys. It shall be the duty of said board: — First. To designate the portions of the cities and towns which shall be tributary to and embraced in the district to be reported upon, and to define the same in their report with plans and maps, and said district and system shall thereafter be known and designated as the South Metropolitan System.

Second. To define and show, by suitable plans and maps, such trunk line and main branches as it shall recommend to be constructed, with outlet. Third. To consider the various methods of disposal of sewage and the application of such methods to any portion of the territory herein mentioned, and to define the methods by which the cities and towns, or parts of the cities and towns, may utilize said trunk line and main branches as an outlet of a system of sewerage and drainage for the cities and towns and said parts of the cities and towns, respectively, and to show the same by plans and maps. Fourth. To employ such engineering and other assistance as may be necessary for carrying out the objects of this resolve, and to cause such surveys and levels to be made as will show on the plans, with substantial accuracy, the location and grades of said trunk line and main branches, and also such surveys and levels in the cities and towns, and parts of the cities and towns, as will enable said board to determine the methods by which the cities and towns may respectively utilize said trunk line and main branches, and to report such methods, with plans showing the main lines by which each may so provide for itself a system of sewerage with its outlet into said trunk line or main branches. Fifth. To define the size and capacity of said trunk line and main branches, and the materials of which they should be constructed, and the manner of construction, and such other particulars as will enable said board to determine the probable expense thereof; and to ascertain and report the cost of the construction of said trunk line and main branches and outlet. All expenses incurred by said board under the provisions of this resolve, but not to exceed thirty thousand dollars, shall be paid out of the treasury of the Commonwealth and shall be assessed by the treasurer of the Commonwealth in two annual instalments for the years eighteen hundred and ninety-eight and eighteen hundred and ninety-nine, upon the cities and towns comprised within the said systems, at the following rates, the same being the proportions for maintaining and operating the said systems made by the apportionment commission in its report to the supreme judicial court in the year eighteen hundred and ninety-six and accepted by said court, to wit: — Boston, twenty-seven and twenty-seven one hundredths per cent.; Brookline, eight and twelve one hundredths per cent.; Dedham, nine and ninety-three one hundredths per cent.; Hyde Park, seventeen and seventy-six one hundredths per cent.; Milton, eight and twenty-five one hundredths per cent.; Newton, fourteen per cent.; Waltham, ten and sixty-nine one hundredths per cent.; Watertown, three and ninety-eight one hundredths per cent. On or before the first day of May in the year eighteen hundred and ninety-nine said board of metropolitan sewerage commissioners shall make a report to the general court upon the matters herein referred to it, with a bill for carrying out any recommendations which it may see fit to make. [*Approved February 15, 1898.*

In pursuance of the above resolve, this Board instructed its engineer to make detailed surveys, studies and estimates for a high-level sewer for the south metropolitan system.

Mr. Joseph P. Davis of New York, consulting engineer, was engaged by this Board to advise in relation to the subject-matter of this report. Mr. Davis has been for many years familiar with the great municipal works of the metropolitan districts of Boston and New York. He was city engineer of Boston for several years, and in that capacity designed its system of main drainage. He was consulting engineer for the State Board of Health during their investigations for the north metropolitan sewerage system.

Mr. H. W. Clark, chemical expert of the State Board of Health, and in charge of the experiment station at Lawrence, was engaged by this Board to examine into the physical and chemical conditions resulting from the discharge of sewage at Moon and Deer islands, and to determine the probable effect of discharging the sewage of the south metropolitan system into the harbor at Moon Island, or elsewhere.

The valleys of the Charles and Neponset rivers embrace an area of about 390 square miles, and have a present population of about 600,000 people, or nearly one-quarter of the entire population of the State. The upper portions of the valleys, above Waltham in the Charles River and above Hyde Park and Dedham in the Neponset, are distinctly rural, and the sewerage problem for these upper districts is not likely to become important. This Board was directed, by chapter 439 of the Acts of 1889, chapter 406 of the Acts of 1895, and acts in amendment thereof, to construct and maintain intercepting sewers in the Mystic, Charles and Neponset River valleys. In arranging the tributary districts of these intercepting sewers, Charlestown, Cambridge, Somerville and Belmont were made parts of the north metropolitan sewerage system, although a large portion of the territory of each is situated in the natural water-shed of the Charles River. These portions of the Charles River valley are consequently excluded from consideration in this report, and the investigations under the above resolve have therefore been confined to the remaining lower or metropolitan sections of the valleys. The south metropolitan sewerage district recommended embraces Waltham, Newton, Watertown, Brighton, Brookline, Dedham, Hyde Park, Milton, Quincy, parts of Boston, West Roxbury and Dorchester, substantially as outlined in the maps accompanying this report.

The Boston Main Drainage Works.

The city of Boston constructed within this metropolitan area, from 1877 to 1884, an extensive system of sewage-disposal works, called the Boston main drainage works, comprising intercepting sewers, pumping station, reservoir and an outlet at Moon Island leading to the waters of the outer harbor.

The territory which was to be tributary to these works is bounded by Charles River, Boston Harbor, Neponset River and Mother Brook and includes an area of about 58 square miles. The lower portion of this territory, comprising about 12 square miles, was to be permanently tributary to the low-level main intercepting sewer and pumping station. The higher portion, comprising about 46 square miles, was to be tributary to a high-level sewer, to be built in the future, which would convey this sewage by gravity to the outfall sewer, and avoid the necessity for pumping the sewage from this large district. The capacity of the low-level pumping system was made sufficient to provide for the sewage from about 3 square miles of the higher district, which might require sewerage before the high-level sewer should be built, in addition to the 12 square miles of the lower district.

The metropolitan intercepting sewers in the Charles and Neponset River valleys, constructed under the authority above mentioned, now discharge into the Boston main drainage works, and large annual rentals have been paid by the Commonwealth to the city of Boston for the disposal of the sewage from these metropolitan districts; for the Charles River district since 1894 and for the Neponset district since 1897.

The territory whose sewerage systems, so far as they are developed, are now tributary to the Boston main drainage works comprises an area of about 121 square miles. This is about double the area which these works were intended ultimately to serve. The reports of the engineers show that the works are now surcharged in times of storm. The officials in charge of the sewer division of the street department have already recognized the need of relief. The report of the superintendent of streets for 1896 contains the following statements: —

> It has always been considered a part of the scheme for intercepting the sewers of Boston that a "high-level" sewer would be built which would intercept the sewage from the high streets in the interior of the suburbs and carry it direct by gravity to Moon Island without the expense of pumping it up (page 329).
>
> The city should proceed with the designing and constructing of what is known as the high-level sewers, which were advocated at the time that this plant was put in, so as to relieve the pumps (page 363).

The Proposed High-level Gravity Sewer.

During the past year the engineer of the Board has made careful and detailed studies of projects for a high-level gravity sewer for the south metropolitan system, including one with an independent outlet off Nut Island. His report is hereto appended and is made a part of this report. It is respectfully recommended to your careful consideration. The consulting engineer, Mr. Davis, has examined and approves the work, report and recommendations of our engineer, and his report is appended and is made a part of this report.

The high-level sewer contemplated by the above-mentioned resolve and now described in this report will give relief to the Boston main drainage works. The system herein described is, however, more comprehensive than the high-level system suggested in the early reports for the Boston main drainage works, and is adapted to the wants of the district as they are now understood, with the added experience of more than twenty years since the preliminary investigations were made for those works.

The high-level sewer will drain territory in Suffolk, Norfolk and Middlesex counties, already drained in part by the existing Charles River and Neponset valley metropolitan sewers now constructed and operated by this commission under the authority of the Commonwealth. These metropolitan sewers will form an integral part of the south metropolitan system, of which the high-level sewer is to be the outlet. The entire system should be under one management, and it therefore seems proper that the high-level sewer and its appurtenances should be constructed and operated by the Commonwealth in the manner adopted for the other intercepting sewers in this vicinity draining metropolitan districts.

The high-level gravity sewer should meet the needs of the district until about the year 1940. The population residing on the high-level and low-level drainage areas at that time is estimated at about 1,550,000 persons. It does not seem desirable that the sewage from so large a population should be concentrated at the Moon Island outlet. The dispersion and diffusion of the sewage into the waters of the outer harbor would be much more rapid and effectual if the sewage should be discharged at more than one outlet. It has therefore seemed advisable to lead the high-level sewer to an outlet at some other point, leaving Moon Island for the future expansion of the reservoirs and outfall works belonging to the low-level system, which the Boston main drainage pumping system should now be called.

The Outlet Recommended.

The chemical expert, Mr. H. W. Clark, has examined into the physical and chemical conditions resulting from the discharge of sewage at Moon Island and Deer Island, and has deduced from them conclusions regarding a discharge of sewage into the deep and powerful tidal currents near Peddock's Island.

A satisfactory position for the outfall of the high-level sewer has been found in the large tidal currents near the westerly end of Peddock's Island. The volume of this current during the ebb tide is about three times that which now receives the sewage discharged at Moon Island, and its velocity and reach are considerably greater.

Sewage could be discharged into this current from a reservoir situated on the westerly end of Peddock's Island, but the most economical and advisable method of conveying sewage into the tidal currents near the westerly end of Peddock's Island is by means of lines of submerged iron pipes leading northerly from Nut Island to an outlet at the bottom of the channel.

The volume of the tidal current near the south-westerly end of Peddock's Island is found to be nearly as great as that near

Deer Island, where a continuous discharge of sewage from the north metropolitan system was recommended by the State Board of Health in 1889. This outlet has been in operation about four years, with results which are highly satisfactory, and equally satisfactory results are expected from it in the future.

The examinations of our engineers and chemical experts coincide in showing that the continuous discharge of sewage into these currents, at the location shown on Plate 5, would be satisfactory for a long series of years, if not perpetually. Should it be found, after the experience of some years, that better results could be attained if the sewage should be stored in a reservoir during a portion of the flood tide, it would then be practicable to construct such a reservoir on Peddock's Island, to which the sewage would be conveyed by independent lines of pipes from the gate-house on Nut Island. Such a reservoir would have discharge channels leading northerly to the tidal current.

The diffusion of the sewage into the waters of the harbor would be more rapid if it were discharged continuously in a stream of moderate size, instead of from a reservoir; as by the latter method the sewage of nearly half a day would be discharged in bulk in a very short time, and its diffusion would become more difficult. In consideration of this, and of the very favorable reports from our engineers and chemist concerning a continuous discharge of sewage into the strong currents near Peddock's Island, and also in consideration of the successful operation of the continuous discharge of sewage from the Deer Island outlet, this Board recommends the method of continuous discharge into these currents as safe and proper for the high-level sewer.

Description of the Proposed Works.

The works comprising the high-level system are described very fully in the report of the engineer. The outlet would consist of lines of cast-iron pipes laid beneath the bottom of the harbor and covered over for protection. Two lines of 60-inch pipes would be laid at first. This number might be increased in the future. The works at Nut Island would comprise a screen house, gate chamber and sand-catcher. The purpose of these structures is to regulate the flow of sewage, and to remove any substances that might cause trouble in the pipes, or make deposits in the harbor.

The route proposed for the high-level sewer is shown on Plate 4. After passing through Quincy, it would follow the valleys of the Unkety and Pine Tree brooks in Milton to the easterly end of Hyde Park, where the Neponset valley metropolitan sewer would be intercepted. It would then be carried through the divide to the valley of Stony Brook, and, following the west side of this valley, would pass north-east of Jamaica Pond to the junction of Castleton and Catalpa streets in West Roxbury. The sizes and elevations of the high-level sewer are given in the report of the engineer.

The sewage of the Charles River valley metropolitan sewer would be intercepted at Ruggles Street, and the slope of the metropolitan sewer between Ruggles Street and Gainsborough Street would be reversed. A connecting sewer, pumping station and force main leading to the high-level sewer would be constructed, and the sewage from the Charles River valley would be pumped about 40 feet to the high-level sewer, the capacity of which has been made sufficient to receive this sewage.

The sewage from a small district in Dorchester and Milton, forming the lower part of the metropolitan district in the Neponset valley, having an area of about 3.8 square miles and a population now somewhat scattered, would remain tributary to the Boston main drainage works until the volume of sewage received at those works becomes so great as to make it necessary to exclude outlying districts which are near other outlets.

The districts which would be left permanently tributary to the main drainage pumping station at Old Harbor Point would include Boston proper, South Boston, and territory in Roxbury, West Roxbury and Dorchester. It would comprise the low districts of Boston which are not now tributary to the existing metropolitan sewers, and would have an area of about 12 square miles. This area is the same in amount as that mentioned in the preliminary report of the Boston main drainage works as belonging specifically to the low-level system. The language of that report in regard to this is: "The commissioners,* in their report, assume that most of the territory above grade forty can eventually be drained by a high-level intercepting sewer by gravity alone without the need of pumping. This leaves about 12 square miles below grade forty to be drained by our present low-level intercepting scheme." (City Doc. No. 70, 1877.)

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* Boston Sewerage Commission, 1875, consisting of E. S. Chesbrough, C.E., Moses Lane, C.E., and Charles F. Folsom, M.D. (City Doc. No. 3, 1876.)

The anticipated population of these districts in the year 1940 amounts to 564,000 persons, and the maximum flow of sewage from them in 1940, including an allowance for storm water, is estimated at about 169,200,000 gallons per day; and this will fully equal the ultimate capacity of the low-level pumping system of the Boston main drainage works.

Quincy Sewerage.

The city of Quincy has recently commenced the construction of a system of sewers, and built a pumping station and force-main to raise the sewage to the outfall sewer of the Boston main drainage works, which is to be used as the outlet for the Quincy sewage under a contract with the city of Boston.

After the completion of the high-level sewer, the sewerage system of Quincy could be divided into two districts. The sewage from the upper district would reach the high-level sewer by gravity. That which would need to be pumped to the high-level sewer could be raised by the pumping plant already installed to pump the Quincy sewage to the Boston outfall sewer. This sewage would need to be raised about 30 feet to flow into the Boston main drainage system when the reservoir at Moon Island is full. The lift to the proposed high-level sewer with outlet from Nut Island would be about 18 feet. All the large pumping plants connected with the metropolitan sewerage systems are the property of the Commonwealth, and it would seem expedient that the pumping plant of the city of Quincy should also belong to the Commonwealth. The sum of $100,000 has been included in the estimated cost of the high-level sewer to cover this purchase.

Cost of the Proposed High-level System.

The cost of the high-level system with a reservoir and discharge channels would be about the same, from $5,250,000 to $5,500,000, whether the outlet were placed at Moon Island or at Peddock's Island, and the annual charges for maintenance and operation would be about $37,500 at either place.

The cost of the high-level system, with a continuous discharge into the strong currents near Peddock's Island, by pipes leading from Nut Island, is estimated at about $4,600,000, and the annual charges for maintenance and operation at about $29,000. The cost of the high-level sewer with an outlet off Nut Island would be about $945,000 less than its cost with intermittent discharge from reservoirs on Peddock's Island. But this is not the entire saving. The annual cost of operating and maintaining a reservoir would be about $10,000, which at 3 per cent. would be the interest of $333,333. This capital would be saved by omitting the reservoir, and the gross capitalized saving effected by placing the outlet off Nut Island with continuous flow is therefore about $1,278,000. These reservoir and outfall works must be enlarged from time to time to provide for increasing quantities of sewage, and this capitalized difference of cost would be thereby increased.

Estimated Annual Expenses.

An estimate has been made of the expenses of the south metropolitan system during the year 1910. This year is taken to represent the average annual expenses of the system during the decennial period from 1905 to 1915; and a comparison has been made between them and the expenses which would result from continuing the payment of a rental to the city of Boston for the disposal of the sewage of the Charles River and Neponset metropolitan sewerage districts. The above decennial period has been taken because it appears to be the first for which such a comparison could be made, as it would be some years before the high-level system could be constructed and put in operation.

The expenses of this system for the year 1910 are estimated as follows: —

Interest and sinking fund charges, about, . . .	$224,400
Maintenance and operation, ...	29,000
Total charges for 1910, ...	$253,400

It seems probable that for purposes of assessments the entire south metropolitan system would be treated as a whole by apportionment commissions. If the expenses of this system are apportioned among the municipalities composing the district on the bases used by former apportionment commissions, namely, the interest and sinking fund charges on the basis of valuation and the maintenance charges on the basis of population, the amounts that would be charged against the cities and towns included in the present Charles and Neponset metropolitan districts would be as follows: —

The aggregate valuation of these cities and towns in the present Charles and Neponset metropolitan districts is about 71.73 per cent. of the valuation of the south metropolitan district, and their aggregate population is about 68.14 per cent. of the population of that district; they may therefore be called upon to pay these percentages of the interest and sinking fund charges and the maintenance charges respectively.

The total amount of the expenses that the existing Charles and Neponset metropolitan sewerage districts might be called upon to pay in 1910 may therefore be as follows: —

For interest and sinking fund, 71.73 per cent. of $224,400,	$160,962
For maintenance, 68.14 per cent. of $29,000, . . .	19,760
Total, ...	$180,722

The remainder, $72,678, of the expenses for the year 1910 would be paid by districts tributary to the high-level sewer, but not now included in the Charles and Neponset metropolitan sewerage districts, viz., portions of Roxbury, West Roxbury, Dorchester and the city of Quincy.

The total annual charge in the south metropolitan district for the year 1910 may be divided somewhat as follows: —

Boston, including areas in present Charles and Neponset metropolitan districts, ...	$106,190
Charles and Neponset valleys, excluding Boston, . .	133,060
Quincy, ...	14,150
Total, ...	$253,400

The above estimated expense to the city of Quincy in the year 1910, as part of the south metropolitan system, is not probably greater than the expense that would come to the city of Quincy in 1910 under the existing contract with the city of Boston for the disposal of the Quincy sewage.

The amount to be asked as rental by the city of Boston in the year 1910 for the disposal of the sewage of the existing Charles River and Neponset metropolitan districts is given in the annual report of the street department for 1896 (page 362) as $102,000. This amount was based upon a valuation of about $5,000,000 for those portions of the Boston main drainage works used by the Charles and Neponset metropolitan sewerage systems; but their cost is to be increased about $500,000 for new reservoirs and other works at Moon Island already in process of construction, and it is probable that this, with the cost of the new pumping plant, may raise the valuation to $6,000,000, and that the rental for 1910 might be increased to about $112,000. This estimate, however, rests upon the assumption that the capacity of the Boston main drainage works would in other respects be equal to the handling of the sewage until the year 1910, which is not likely to be the case. The city officials stated in 1896 that the city of Boston should proceed to construct a high-level sewer to relieve the pumps. Such additional outlay by the city would greatly increase any charge for rental based upon the valuation of the works.

Using the figures for rental given above, the expenses of the Charles River and Neponset valleys for the year 1910 would be as follows: —

Rental,	$112,000
Interest and sinking fund,	64,130
Maintenance,	5,000
Total,	$181,130

The expense to the Charles River and Neponset valleys for the south metropolitan system in 1910 is estimated at $180,722. This is not materially different from the expense in that year, if the rental system could be continued until that time. The construction of the high-level sewer by the Commonwealth would present the great advantage that the district would own the system at the end of forty years, instead of being obliged to continue the payment of rental perpetually.

Although the expenses to the Charles River and Neponset valleys are about the same in the above comparison, there would be about $20,000 more paid into sinking funds in each year of this decennial period in the case of the south metropolitan system than in the case of continued rental. This would be a relative saving, as the money would be paid for a permanent investment instead of rent.

Accompanying this report is a draft of the bill called for in the resolve, for carrying out the recommendations of this report.

The questions referred to this Board by the resolve have been examined with great care. The conclusions reached are based upon expert investigations. The necessity for at once providing relief for the congested condition of the Boston main drainage works and an outlet for the rapidly increasing volume of sewage of the south metropolitan district cannot be too strongly urged. Your Board feels that it has outlined a method of relief that will be effectual, and consistent with the proper treatment of the sewerage problems of this great district. This relief may be obtained at a reasonable cost, considering the wealth and population of the municipalities to be benefited.

HOSEA KINGMAN,
TILLY HAYNES,
GEORGE A. KIMBALL,
Metropolitan Sewerage Commissioners.

BOSTON, Feb. 11, 1899.

EXPENSES OF INVESTIGATIONS FOR HIGH-LEVEL SEWER FOR RELIEF OF CHARLES AND NEPONSET RIVER VALLEYS.

Appropriation made in 1898, ...		$30,000
Salaries of commissioners, engineers, experts and assistants, ...	$17,201 75	
Travelling expenses, ...	399 45	
Engineering instruments, office supplies and incidental expenses, ...	877 71	
Miscellaneous supplies for surveying and boring parties, ...	483 19	
Boats and other supplies for hydrographic survey, ...	481 53	
Laborers and boatmen for boring and hydrographic works, ...	4,355 74	
Printing maps and report, ...	1,878 59	
	$25,677 96	

AN ACT

To provide for the Building, Maintenance and Operation of a High-level Sewer for the Relief of the Charles and Neponset River Valleys.

Be it enacted, etc., as follows:

Section 1. The board of metropolitan sewerage commissioners, constituted under the authority of chapter four hundred and thirty-nine of the acts of the year eighteen hundred and eighty-nine shall, for the purpose of constructing, maintaining and operating a system of sewage disposal for the south metropolitan system as hereinafter defined, construct, maintain and operate such main sewers and other works as shall be required for a system of sewage disposal for said district in substantial accordance with plans outlined in a special report of said board to the legislature of eighteen hundred and ninety-nine. Said board, for the purposes aforesaid, may make all contracts necessary for the construction of the sewers and works aforesaid, and may, where deemed advisable, carry on said construction by day labor.

Section 2. The south metropolitan system shall include the present Charles river valley metropolitan sewerage district, comprising a portion of Boston, the cities of Newton and Waltham and the towns of Watertown and Brookline; the present Neponset valley metropolitan sewerage district, comprising a portion of Boston and the towns of Dedham, Hyde Park and Milton; also Quincy and such portions of Dorchester, Roxbury and West Roxbury as are not included in the present metropolitan sewerage areas and which are so situated as to be drained into the proposed high-level sewer substantially as outlined on maps contained in the special report of the metropolitan sewerage commissioners to the legislature of eighteen hundred and ninety-nine.

Section 3. Said board acting on behalf of the Commonwealth may take by purchase or otherwise any lands, water-courses, rights of way or easements, and may take by purchase or otherwise or enter and use any existing sewers or parts of sewers necessary for the carrying out under the provisions of this act of the recommendations of said metropolitan sewerage commissioners contained in its said report. When any lands, water-courses, rights of way or easements, or any sewers or parts of sewers are so taken or entered and used in any manner other than by purchase or agreement, said board shall within thirty days of said taking or entering and using cause to be recorded in the registry of deeds for the county or district in which such lands, water-courses, rights of way or easements, or sewers or parts of sewers lie, a description of the same as certain as is required in a common conveyance of land, with a statement of the purpose for which the same is taken or entered and used, which description shall be signed by a majority of said board; and the fee of the lands, or if an easement or other estate less than the fee therein be specified and described in the deed of purchase or the description and statement of taking to be recorded as aforesaid such easement or estate therein as is so specified and described and the water-courses, rights of way or easements, or sewers or parts of sewers so taken or purchased shall vest in the Commonwealth, which shall pay, in the manner hereinafter described, all damages that shall be sustained by any person or corporation by reason of such taking or entering as aforesaid. Such damages are to be agreed upon by said board and the person or corporation injured; and if the parties cannot agree a jury in the superior court of the county in which the property taken or damaged is situated may be had to determine the same in the same manner as a jury is had and damages are determined in the case of persons dissatisfied with the estimate of damages sustained by the laying out of ways in the city of Boston: *provided, however*, that no suit for such damages shall be brought after the expiration of two years from the date of the recording of the taking or entering as herein required.

SECTION 4. Said board may, for the purposes aforesaid, carry and conduct any sewer by it to be made and constructed under or over any water-course, or any street, turnpike road, railroad, highway or other way in such manner as not unnecessarily to obstruct or impede travel thereon; and may enter upon and dig up any such road, street or way for the purpose of laying sewers beneath the surface thereof and for maintaining and repairing the same; and in general may do any other acts and things necessary or convenient and proper for the purposes of this act. In entering upon and digging up any such road, street or way of public travel it shall be subject to such reasonable regulations as may be made by the mayor and aldermen or selectmen of the cities and towns respectively wherein such works shall be performed.

Section 5. Whenever said board shall dig up any road, street or way, as aforesaid, it shall so far as practicable restore the same to as good order and condition as the same was in when such digging commenced. And the Commonwealth shall at all times indemnify and save harmless the several cities and towns within which such roads, streets or ways may be against all damages which may be recovered against them respectively, and shall reimburse to them all expenses which they shall incur by reason of any defect or want of repair in any road, street or way caused by the construction of any of said sewers, or by the maintaining or repairing of the same: *provided*, that said board shall have due and reasonable notice of all claims for such damages or injury and opportunity to make a legal defence thereto.

Section 6. Said board may also alter or change the course or direction of any water-course, or may with the consent of the mayor and aldermen of cities or selectmen of towns alter or change the location or grade of any highway, townway, public street or way of travel crossed by any sewers constructed under the provisions of this act, or in which such sewers may be located.

Section 7. Said board shall at all times keep full, accurate and complete accounts of its receipts, expenditures, disbursements, assets and liabilities, and shall include an abstract of the same in its annual report to the general court.

Section 8. Any city or town within whose limits any main sewer shall have been constructed under the provisions of this act shall connect its local sewers with such main sewer, subject to the direction and control of said board, and any person, firm or corporation may, subject to the direction, control and regulation from time to time of said board, and subject to such terms, conditions and regulations as each city or town may prescribe, connect private drains with said main sewer. The sewerage systems of all drainage areas, not now sewered, in the south metropolitan system, which are constructed after the passage of this act shall be in accordance with the so called separate system of sewerage.

Section 9. Any person or persons who shall wantonly or maliciously destroy or injure any sewer or other property, held or used by said board by the authority and for the purposes of this act, shall forfeit and pay to the Commonwealth three times the amount of the damages that shall be assessed therefor, to be recovered by any proper action. And every such person or persons may, on complaint or indictment and conviction of either of the wanton or malicious acts aforesaid, be punished by a fine not exceeding one thousand dollars and imprisonment not exceeding one year.

Section 10. Said board may from time to time, and at public or private sale as they may deem best, dispose of any property, real or personal, no longer needed for the construction, maintenance or operation of the sewers authorized by this chapter: *provided, however*, that such sale shall not impair the maintenance and operation of said sewers.

Section 11. Real estate so sold may be conveyed, subject to such easements, reservations and restrictions as said board may deem necessary to secure the maintenance, renewal and operation of said sewers, by deed duly executed by said commissioners on behalf of the Commonwealth with or without warranty.

Section 12. The net proceeds of such sales, after deducting all necessary expenses incurred thereby, shall be paid into the treasury of the Commonwealth and shall be credited to and form a part of the fund to be used in construction or maintenance of said sewers.

Section 13. Any money which may be collected or received by the treasurer and receiver general of the Commonwealth from checks deposited with said board by bidders for work, and by said board declared forfeited, and any sums collected or received by said treasurer and receiver general for breach of any contract made with said board, shall be applied to the payment of interest upon the loan issued under the authority of this act.

Section 14. To meet the expenses incurred under the provisions of this act for the construction of the sewerage works recommended, the treasurer and receiver general shall, with the approval of the governor and council, issue from time to time scrip or certificates of debt, in the name and behalf of the Commonwealth and under its seal, to an amount not exceeding four million, six hundred thousand dollars, for a term not exceeding forty years from the date hereof. Said scrip or certificates of debt shall be issued as registered bonds or with interest coupons attached, and shall bear interest not exceeding four per cent. per annum, payable semi-annually on the first days of March and September in each year. Said interest and scrip or certificates shall be payable, and when due shall be paid, in gold coin or its equivalent. Said scrip or certificates of debt shall be designated on the face thereof, South Metropolitan Sewerage Loan; shall be countersigned by the governor and shall be deemed a pledge of the faith and credit of the Commonwealth, redeemable at the time specified therein in gold coin or its equivalent, and shall be sold and disposed of at a public auction, or in such other mode, and at such times and prices, and in such amounts and at such rate of interest, not exceeding four per cent. per annum, as the treasurer and receiver general with the approval of the governor and council shall deem for the best interest of the Commonwealth. The treasurer and receiver general shall on issuing any of said scrip or certificates of debt establish a sinking fund and apportion thereto from year to year an amount sufficient with its accumulations to extinguish the debt at maturity. But in such apportionment of a sinking fund the assessment shall be at the rate of one eightieth part of the whole amount in each of the first ten years, one sixtieth part in each of the second ten years, one thirtieth part in each of the third ten years, and the remainder equally divided in the next ten years. Any premium realized in the sale of said scrip or said certificates of debt shall be applied to the payment of the interest on said loan as it accrues.

SECTION 15. The expense for the construction of the Charles river system incurred under chapter four hundred and thirty-nine, acts of eighteen hundred and eighty-nine, and the expense for the construction of the Neponset river system incurred under chapter four hundred and six, acts of eighteen hundred and ninety-five, and acts in amendment thereof, shall be assessed upon the cities and towns of the south metropolitan district as hereinafter provided.

SECTION 16. The supreme judicial court sitting in equity shall, on the application of said board after notice to each of the cities and towns hereinbefore named, appoint three commissioners, who shall not be residents of any of the cities or towns mentioned in this act, who shall after due notice and hearing and in such manner as they shall deem just and equitable determine the proportion in which each of the cities and towns hereinbefore named shall annually pay money into the treasury of the Commonwealth for the term of five years next following the year of the first issue of said scrip or certificates, to meet the interest and sinking fund requirements for each of said years as estimated by said treasurer, and to meet the cost of maintenance and operation of said system for each of said years, as estimated by the said board and certified to said treasurer, and any deficiency in the amount previously paid in, as found by said treasurer, and shall return their award into said court; and when said award shall have been accepted by said court the same shall be a final and conclusive adjudication of all matters herein referred to said commissioners and shall be binding on all parties.

SECTION 17. Before the expiration of said term of five years and every five years thereafter other commissioners, who shall not be residents of any of the cities or towns mentioned in this act, shall be appointed as aforesaid, who shall in such manner as they deem just and equitable determine the proportion in which each of said cities and towns in each of said systems shall annually pay money into the treasury of the Commonwealth as aforesaid for the next succeeding term of five years, and shall return their award into said court; and when said award shall have been accepted by said court the same shall be a final and conclusive adjudication of all matters herein referred to said commissioners and shall be binding on all parties.

SECTION 18. The amount of money required each year from each such city and town to meet the interest, sinking fund requirements and cost aforesaid for that system in which it is included for each year, and deficiency, if any, shall be estimated by said treasurer in accordance with the proportion determined as aforesaid, and shall be included in and made a part of the sum charged to such city or town, and be assessed upon it in the apportionment and assessment of its annual state tax, and said treasurer shall in each year notify each such city and town of the amount of such assessment, which amount shall be paid by the city or town into the treasury of the Commonwealth at the time required for the payment and as a part of its state tax.

SECTION 19. The clerk of the board of metropolitan sewerage commissioners, or such other person as said board may designate, may have advanced to him from the money in the treasury of the Commonwealth received from the loan hereinbefore authorized, such sums, not exceeding ten thousand dollars at any time, as the auditor may certify to be necessary to enable said board to make direct payment upon its pay rolls and other accounts. The person so designated by said board shall give a bond with sufficient sureties, to be approved by the auditor of the Commonwealth, in the sum of ten thousand dollars.

SECTION 20. As soon as may be after expending such advance, and in any case within thirty days from the receipt thereof, the officer who has received money of the Commonwealth under the provisions of the preceding section shall file with the said auditor a statement in detail of the sums expended subsequent to the previous accounting, approved by said board, and, where it is practicable to obtain them, receipts or other like vouchers of the persons to whom the payments have been made.

SECTION 21. The supreme judicial court shall have jurisdiction in equity to enforce the provisions of this act, and shall fix and determine the compensation of all commissioners appointed by said court under the provisions hereof.

SECTION 22. This act shall take effect upon its passage.

REPORT OF THE CONSULTING ENGINEER.

NEW YORK, N. Y., Feb. 1, 1899.

HOSEA KINGMAN, TILLY HAYNES, GEORGE A. KIMBALL,
Metropolitan Sewerage Commissioners.

GENTLEMEN: — In compliance with your request, I respectfully submit the following statement of my views regarding the project of your chief engineer, Mr. Brown, for a system of intercepting sewers for and the disposal of the sewage of the high-level division of the south metropolitan sewerage district.

Mr. Brown has furnished me from time to time, as they were completed, maps and profiles showing the proposed location and dimensions of the sewers and tunnels, the borings, depths of excavation, etc., and a copy of the report, with maps, of his assistant, Mr. Smith, upon float experiments in the harbor; of the report of the chemist, Mr. Clark, upon the degree and area of pollution of the harbor waters caused by the present discharge of sewage at Moon and Deer islands; copies of reports by himself upon special subjects, and a copy of his final report.

With him I have examined the route proposed for the main sewer through most of the territory with which I had not already become familiar by examinations made in former years, and have inspected the outlets of existing systems at Moon and Deer islands during times of sewage discharge, and also the site of the proposed outlet near Peddock's Island.

As marked out by him, the south metropolitan sewerage district, including the main drainage or low-level division, contains cities and towns covering an area of 121 square miles.

He estimates that in 1940 the population in the entire district may be 1,550,000; and, for the purpose for which he uses it, this estimate does not appear to me to be too large.

He assigns an area of about 109 square miles, with a population of 986,000, to the high-level division of the district; and an area of 12 square miles, with a population of 564,000, to the low-level division (main drainage).

At the time the main drainage works were planned, the carrying capacity of the low-level division was based upon the quantity of sewage, as then estimated, that would be furnished by a population of 600,000 people and ¼ inch rainfall in twenty-four hours on an area of 15 square miles.

In estimating the required capacity, it was assumed that the sewage, exclusive of rain water, would not exceed, as a daily average, 75 gallons per person.

The quantity of dry-weather sewage is somewhat greater than the quantity of the water supply. The latter at that time was, in Boston, about 80 gallons per head per day; but there were good grounds for belief that the consumption would be brought down to and kept at less than 70 gallons per head. Instead, however, it has increased to upwards of 100 gallons per head, and, so far as can be foreseen, is likely within a few years to largely exceed even this figure.

Mr. Brown, therefore, in drawing the line between the territory of the high-level system and that of the low-level, has very properly reduced the area of the latter below that for which the works were designed, and it may be found advisable in the future to make still further reduction.

To determine the capacity to be given a system of sewers, it is necessary to estimate the maximum rate of flow — which will occur in times of rain at some future period. For the south metropolitan district Mr. Brown places it at 300 gallons per head per day in 1940, and in his report gives his reasons for so doing, at some length.

For intercepting sewers that are to receive the sewage from a territory the greater part of which is, or will be, sewered upon the separate system, this rate, at first thought, may appear too large; but after studying the question with care, and considering the possibility that at some future time a greater area and population than now contemplated may be made tributary to the system, I believe that the high-level sewers should be proportioned for a flow at the rate of 300 gallons per head per day.

Mr. Brown recommends that the sewage be discharged into the harbor at a point near the south end of Peddock's Island,

and that the discharge be continuous. The choice of location for an outlet lies between this point and the one at Moon Island.

The discharge of sewage into the waters of a frequented harbor should be so made that the sewage will be quickly lost to the senses and even to chemical tests. This may be done by making the discharge into quick currents of large volumes, where the sewage will be soon dispersed and undergo great dilution.

The observations and analyses of Mr. Clark show that a discharge of 40,000,000 gallons per day in the current of the main channel near Deer Island causes a visible pollution of comparatively limited area, and that in a run of about a mile the sewage becomes so dilute as to be practically lost to chemical test; also that a discharge of 22,000,000 gallons in less than an hour into the ebb current off Moon Island visibly pollutes a much larger area, and requires considerable more time to be dispersed and lost. If all the sewage from the south metropolitan district, or of 1,550,000 people, were to be discharged intermittently at this latter point, there is great probability that a nuisance would be created. It is advisable, therefore, as recommended by Mr. Brown, that the discharge from this district be made at both the available points, and that the larger portion, or that of the high-level division, be made in the quicker current of larger volume which runs to the west of Peddock's Island.

It is advisable, when the conditions are favorable, to make the discharge continuously, as the sewage is much more quickly dispersed than when discharged intermittently. The directions and velocities of the ebb and flood currents about Peddock's Island, and the path that will probably be taken by the sewage, as shown by the float experiments, offer conditions that on the whole are favorable to a continuous discharge; and I am of opinion that Mr. Brown is right in advising that, while the works be so built that reservoirs may be added if found necessary in the future, the discharge be made continuously at first, and until the necessity for reservoirs may be made evident.

I can speak only in general terms of the proposed location of the main sewer, as I have not been able to give it much study. I believe it to have been carefully determined, and that it will need only such minor changes in favor of smaller cost as the more detailed surveys made before construction begins usually show to be advisable.

I find the unit prices used in the estimates of cost to be sufficient, and I have made estimates of the cost of a large portion of the main sewer which confirm those made by Mr. Brown. I believe that his estimate of the cost of the entire scheme is trustworthy.

To summarize, I concur with Mr. Brown in the opinions: —

That the city of Quincy and the areas tributary to the Charles River and Neponset River sewers should be included in the high-level division of the south metropolitan sewerage district.

That the sewerage system of this division should have capacity to collect and convey to its outlet the sewage from a population of 986,000.

That the dimensions of the sewers should be proportioned for a flow of 300 gallons per head per day.

That the outlet should be in the channel at the south-west end of Peddock's Island.

That a more satisfactory disposal of the sewage will result from discharging it continuously during both ebb and flood tides than from storing it in the reservoirs to be discharged during ebb tide.

I believe that the route of the main sewer has been selected with good judgment, and that the estimates of cost of the system have been made with care, and are trustworthy.

Respectfully,

JOS. P. DAVIS,
Consulting Engineer.

REPORT OF THE CHIEF ENGINEER.

BOSTON, Jan. 21, 1899.

HOSEA KINGMAN, TILLY HAYNES, GEORGE A. KIMBALL,
Metropolitan Sewerage Commissioners.

GENTLEMEN: — The resolve relative to the high-level sewer for the relief of the Charles and Neponset River valleys, under which these investigations have been made, directs the Board of Metropolitan Sewerage Commissioners "to consider and report upon a high-level system of sewerage for the Charles and Neponset River valleys," and, among other things, "to designate the portions of the cities and towns which shall be tributary to and embraced in the district to be reported upon, and to define the same in their report with plans and maps."

The Massachusetts Drainage Commissioners reported in 1886 upon the sewerage of the Charles and Neponset valleys. They found that the population of the Charles River valley was so distributed that it could be divided by a line near Waltham into two unequal parts, one distinctly rural, the other urban in its character, each requiring a different method for the solution of its sewerage problem. They recommended that the sewage of the urban or metropolitan portion, should be conveyed to the shore and be discharged into the sea. They found that the rural district above Waltham required special recommendations for each individual town. Of these only three, Milford, Franklin and Wellesley, had public water supplies at that time. The commissioners concluded that these were the only ones which then required special recommendations in regard to sewage disposal, and they advised that the method of land filtration should be adopted for each.

The commissioners found the Neponset valley to be divided into two radically different communities by the Fowl Meadows, a broad tract of marsh land extending about 6 miles along the river above Hyde Park. They recommended that the sewage of the lower or urban portion be conveyed to and be discharged into the sea. They found that the rural district above Hyde Park and Dedham required special recommendations for each individual town. Four of these, Sharon, Stoughton, Norwood and Canton, were the only ones at that time requiring sewage disposal. Land filtration was recommended for each.

The State Board of Health made in 1897 a report upon the sanitary condition and improvement of the Neponset Meadows. That Board considered that the sewerage of the valley as far up as Hyde Park and Dedham was provided for by the construction of the main trunk sewer in the valleys of the Neponset River and Mother Brook, authorized by chapter 406 of the Acts of 1895, and already substantially completed. The Board also concluded that "the disposal of the sewage of the towns and villages in the upper portion of the valley can be most satisfactorily accomplished by separate treatment upon land, as is done in many other towns similarly situated, rather than by a general system of sewerage for the upper portions of the valley."

The valleys of the Charles and Neponset are now in very much the same condition as in 1886 and 1897, when reported upon by the above-mentioned boards. The upper portion of each is still distinctly rural in character, and is likely to remain so for many years.

The 14 towns in the valley of the Charles above Newton and Waltham, whose centres of population are within the watershed of the Charles, now include but 6 which have a public water supply. The population of these 14 towns in 1895 was 37,642, and in 1940 it will have increased perhaps to 100,000. If at that time all of these towns shall have introduced water supplies, their total water consumption at that time may be 6,000,000 or 7,000,000 gallons per day, and their total volume of sewage, including private water supplies and leakage, may be some 12,000,000 or 15,000,000 gallons per day, rain water being excluded. This quantity, divided among 14 centres of population, would not give at any one an amount of sewage difficult to dispose of by land filtration, — the method recommended by the Massachusetts Drainage Commission for the 3 towns in this valley reported upon by them.

Similarly, the 5 towns in the Neponset valley above Dedham, whose centres of population are within the water-shed of the Neponset, had a total population in 1895 of 19,193, and in 1940 will have a population of perhaps 50,000, and a volume of sewage of some 6,000,000 or 7,000,000 gallons per day. This, divided among 5 centres of population, would not give at any one a volume of sewage difficult to dispose of on land. The Massachusetts Drainage Commission recommended in 1886 this method for 4 of these towns.

The information collected by the above-mentioned boards has been examined again carefully. The study of it, together with such additional facts as have been obtained, leads to the conclusion that conveying to distant places the sewage of the scattered communities in the rural portions of the Charles and Neponset valleys is not likely to become expedient. The studies relating to the high-level or south metropolitan sewerage district contemplated in this resolve have therefore been limited to the urban portions of these valleys. The city of Quincy has been included in the project, as it is expected that the high-level sewer will pass through that city, whatever may be its final location.

The valleys of the Charles and Neponset rivers designated in the resolve are shown on Plate No. 1. The outlines of the territory considered in the studies relating to the south metropolitan sewerage district are also shown on this plate, and include, in whole or in part, Waltham, Newton, Watertown, Brighton, Brookline, Dedham, Hyde Park, Milton and Quincy, and parts of Boston, West Roxbury and Dorchester.

BOSTON MAIN DRAINAGE.

The city of Boston constructed, during the period from 1877 to 1884, a comprehensive system for the disposal of its sewage. These works, known as the Boston main drainage, were designed for the relief of Boston and some of the neighboring municipalities, and are shown in outline on Plate No. 2.

The works comprise intercepting sewers along the borders of the city, into which the district sewers discharge; a main sewer, with which the intercepting sewers connect, and which conveys the sewage to a pumping station; pumping machinery to raise the sewage; a tunnel under Dorchester Bay; an outfall sewer leading to Moon Island; a reservoir on Moon Island, with a discharge channel leading to the tidal currents in the harbor.

The sewage collected in the reservoir during the latter part of the ebb tide and the whole of the flood tide is discharged into the sea during the first two or three hours of the flood tide.

The territory which it was expected would eventually be tributary to these works is bounded by Charles River, Boston harbor, Neponset River and Mother Brook. It comprises about 58 square miles. It is shown on Plate No. 2. The lower portion of this territory, not more than 40 feet above mean low water, and comprising about 12 square miles, was expected to be always tributary to the low-level intercepting sewers, and thus the sewage from this portion would always need to be pumped. The sewage from the higher portion of this territory, more than 40 feet above mean low water, and comprising about 46 square miles, was expected to be conveyed by means of a high-level sewer, to be built in the future, which would convey this sewage by gravity to the outfall sewer beyond the pumping station, thus avoiding the necessity for pumping the sewage from these districts. A branch was left in the outfall sewer, to which a high-level sewer might be connected. As it might be some years before a high-level sewer would be built, and as some portions of the higher districts might require sewerage in the mean time, it was thought best to give to the low-level system a capacity sufficient to provide for the sewage from 3 square miles of the higher districts, in addition to the 12 square miles of low districts properly belonging to that system. The capacity of the main sewer at the pumping station was therefore made sufficient to receive the sewage from 15 square miles of territory. This district is shown on Plate No. 2 by the orange tint.

The development of the sewerage systems in this territory has, however, been very different from what was anticipated at the outset. No high-level sewer having as yet been built, large districts intended to be sewered by gravity have been made tributary to the pumping system. The Legislature of

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1889 added all those portions of Waltham and Watertown which are north of the Charles River, and therefore outside of the territory originally contemplated. Similarly, the Legislature of 1895 added large districts in Dedham, Hyde Park and Milton, south of the territory originally contemplated. These Legislative enactments placed the above districts, as well as large districts within the original 58 square miles, under the management of the Metropolitan Sewerage Commissioners, with authority to build two intercepting sewers, known respectively as the Charles River valley sewer and the Neponset valley sewer. These have been constructed, and their sewage now flows into the pumping system of the Boston main drainage. Besides these extensive additions, the city of Boston has made a contract with the city of Quincy, by virtue of which the sewage of Quincy is received in the outfall sewer and is conveyed to Moon Island.

Thus, instead of the original 15 square miles, there are at the present time tributary to the pumping system of the Boston main drainage all the sewered portions of the 58 square miles originally designated, and the large areas above referred to north of the Charles River and in the Neponset valley.

The territory whose sewerage systems, so far as they are developed, are now connected with the Boston main drainage, is shown on Plate No. 2.

The original district of 58 square miles is shown by two tints. The buff tint represents the 43 square miles of high land whose sewage was originally intended to flow by gravity in a proposed high-level sewer, but whose sewers are now connected directly or indirectly with the pumping system of the Boston main drainage. The orange tint represents the 15 square miles originally intended as the low-level district of the Boston main drainage, and is the territory whose sewage was expected to be permanently pumped at Old Harbor Point.

The districts added by legislative enactments are shown by the pink tint. These, as well as the portions of the district tinted yellow which are enclosed by the pink lines, are under the management of the Metropolitan Sewerage Commissioners.

The city of Quincy, whose sewage is pumped to the outfall sewer of the Boston main drainage, is shown by the brown tint.

The total area of the territory which would become tributary to the Boston main drainage works if the present arrangement is not modified, is about 121 square miles, or more than double the area of the territory contemplated at the time the works were built.

The carrying capacities of the Boston main drainage works were determined in 1888 by the State Board of Health, after elaborate studies and calculations. The results were published in the "Report upon the Sewerage of the Mystic and Charles River Valleys" (Senate Document, No. 2, 1889). The following quotations are from the report of F. P. Stearns, Chief Engineer, pages 88 and 89: —

> The tunnel under Dorchester Bay has a brick lining, and its section is circular, 7.5 feet in diameter. Its flowing capacity depends upon the difference in level of the surfaces of the sewage in the chambers at its ends. The height of the sewage in the chamber at the lower end varies with the height in the reservoir at Moon Island. Consequently, the flowing capacity of the tunnel will be least when the reservoir is full. When the reservoir is full and the deposit sewers at the upper end of the tunnel are also full, the sewage at the upper end of the tunnel will be 5.38 feet higher than at the lower end, and under these conditions the tunnel will carry 122,000,000 gallons per day.

But it is not practicable to allow the deposit sewers to become full without interrupting the removal of the deposits by the present method. The head of 5.38 feet is therefore reached when the reservoir is at a lower level, and the duration of somewhat greater flows, possible when the reservoir is partly full, is correspondingly reduced. The above quantity, 122,000,000 gallons per twenty-four hours, therefore, may be regarded as a practical limit to the present carrying capacity of the tunnel for continuous service due to the methods now in use for operating the works. Modifications might be made which would permit the tunnel to be used to convey a larger amount. Concerning the above, Mr. Stearns in his report says: —

> My conclusion with regard to capacity is, that by moderate additions the main drainage works can be made to take care of a maximum of 154,000,000 gallons per day.

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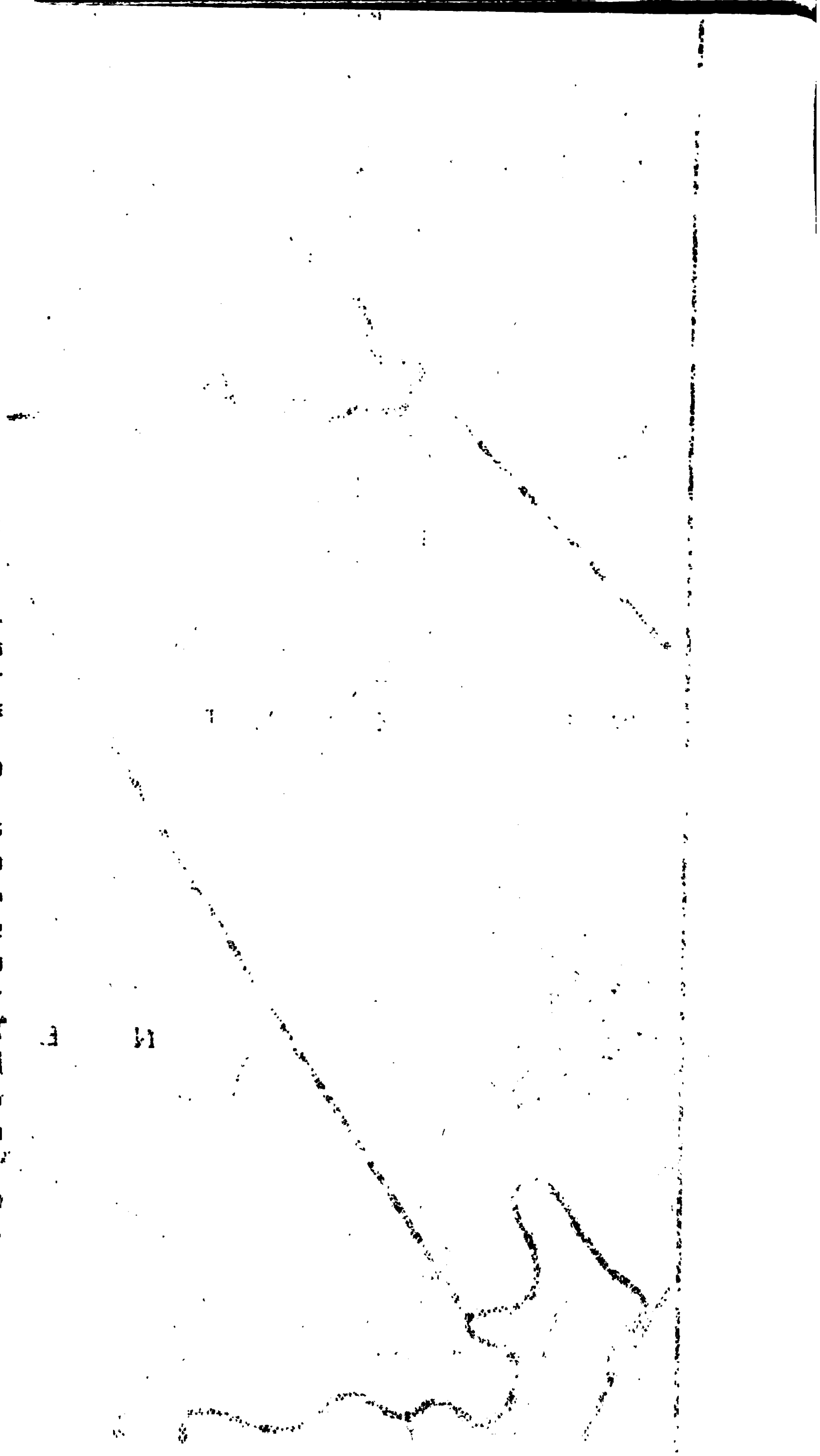

The capacities of the Boston main drainage have recently been reviewed by an independent study of the dimensions and levels of the works, and the results agree substantially with those reported above. The conclusions reached by this study are that the present limit to the capacity of the pumping system of the Boston main drainage works is about 122,000,000 gallons per twenty-four hours, this being the carrying capacity of the tunnel under Dorchester Bay so long as the present method of operating the works is continued; also that its capacity can be increased to about 154,000,000 gallons per twenty-four hours, by suitable modifications in the structures and in the method of operating the deposit sewers; and that this latter quantity should be regarded as the ultimate carrying capacity of the pumping system of the Boston main drainage works.

To determine how soon the sewage from the districts now connected with the Boston main drainage may attain the volumes determined upon as the capacities of the works, the following study has been prepared of the anticipated populations, rates of flow per capita, and the volume of flow of sewage in different years.

Any system of works for the relief of the Boston main drainage ought to be built to meet the needs of the district for at least forty years, and estimates have been made of the anticipated populations and quantities for every fifth year, from 1900 to 1940.

The Anticipated Volume of Sewage from the Territory the Sewered Areas of which are now Tributary to the Boston Main Drainage Works.

The sewage collected in an intercepting sewer is made up from several sources. These vary somewhat in different localities. In this vicinity they would mainly be the public water supply, private water supplies, leakage into the sewer, and the storm water which enters the sewers. These sources being usually distributed over the district somewhat as the population is distributed, it is customary to regard the amount of sewage as proportional to the population, in a general sense, and to estimate its volume approximately by a per capita rate.

Population.

A prediction of the probable future population of any territory is usually based upon the growth of population in the past, as shown by the census records, and also upon a study of the rate of growth in districts of like character in other places, whose development has already passed the stage in which the district in question is found to be.

A very careful study of the populations of 34 cities and towns in the Boston metropolitan district was made by the State Board of Health, and was published as Appendix No. 1 to the report upon a metropolitan water supply, House Document, No. 500, February, 1895. In this estimate the populations from 1850 to 1890 were taken from the census reports; those from 1895 to 1930 were estimated.

After the publication of the returns of the census of 1895, these predicted populations up to the year 1920 were carefully revised by the Metropolitan Water Board. This revision has since been completed and extended by this office to the year 1940 for the municipalities here under consideration, and an estimate of the future population of Dedham has been added. The results are given in the following table: —

Estimate of the Anticipated Populations in the Districts Tributary to the South Metropolitan and Boston Main Drainage Systems, based upon the Revised Estimate of Populations by the Metropolitan Water Board.

CITIES AND TOWNS.	POPULATIONS.								
	1900.	1905.	1910.	1915.	1920.	1925.	1930.	1935.	1940.
Boston, less East Boston and Charlestown,	462,206	510,145	562,992	615,000	673,700	738,500	807,000	883,000	970,000
Brookline,	20,200	25,000	31,000	38,400	47,400	58,000	70,000	81,000	92,000
Newton,	33,700	41,100	50,100	60,600	71,500	83,500	96,000	108,000	119,000
Watertown,	9,300	11,200	13,400	16,100	19,300	23,300	28,100	33,000	37,000
Waltham,	23,600	28,300	34,000	40,800	49,000	58,800	69,000	79,000	89,000
Dedham,	8,000	9,500	12,000	16,000	21,000	27,000	34,000	42,000	50,000
Hyde Park,	14,100	16,600	19,600	23,300	28,000	34,000	41,500	50,000	58,000
Milton,	6,900	8,600	10,700	13,300	16,200	19,700	23,800	29,000	35,000
Total Boston main drainage, Charles River and Neponset valleys,	578,006	650,445	733,792	823,500	926,100	1,042,800	1,169,400	1,305,000	1,450,000
Quincy,	25,900	32,400	40,500	49,800	58,800	68,800	79,400	90,000	100,000
Total,	603,906	682,845	774,292	873,300	984,900	1,111,600	1,248,800	1,395,000	1,550,000

According to this table, which gives the estimated populations for every fifth year from 1900 to 1940, the aggregate population of all the municipalities mentioned in the table, excepting Quincy, may be expected to amount to 578,006 in the year 1900 and 1,450,000 in the year 1940. The sewage from Quincy enters the Boston main drainage not at the pumping station but at the outfall sewer, and the population which would be tributary to the outfall sewer under these conditions may be expected to amount to about 603,906 in the year 1900 and 1,550,000 in the year 1940.

The Rate of Flow of Sewage per Capita.

The metropolitan sewerage systems and the Boston main drainage works have now been in operation for several years. They give an opportunity to determine practically the amount of sewage per capita in the districts which are tributary to them.

Measurements have been made in the Charles River valley metropolitan sewer, which is within the area here under consideration as tributary to the high-level sewer, during days when the flow was in a fairly average condition. In four cases the measurements were continued during twenty-four consecutive hours. The average rate per capita given by them is about 141 gallons per head per day. In nine other cases the measurements were continued during ten hours of the day, and a rate per twenty-four hours was deduced from these observations, on the basis of the four series of twenty-four hours. The average of the entire group of thirteen series of observations was 142 gallons per head per day, based upon the aggregate gross populations of the tributary municipalities. The results are given in the following table: —

Rate of Flow per Capita, as determined by Measurements in the Charles River Valley Sewer.

DATE OF MEASUREMENT.	Gross Population of the Territory Drained.	RATE OF FLOW IN THE SEWER (GALLONS).	
		Daily Flow.	Rate per Head per Day.
1896.			
September,	102,000	14,420,000	141
December,*	102,000	16,935,000	166
1897.			
January 11,	102,000	15,021,000	147
February 1,	102,000	11,744,000	115
March 11,	107,245	20,370,000	190
April 2,	107,245	18,694,000	174
April 24,*	107,245	17,030,000	159
June 3,	107,245	12,390,000	116
June 26,	107,245	13,880,000	129
August 7,*	107,245	13,640,000	127
October 2,	107,245	13,056,000	122
October 29,*	107,245	11,751,000	110
December 2,	107,245	15,630,000	146
Mean,	. .	. .	142

* These measurements were continued during twenty-four hours.

The records of the pumping station at Old Harbor Point cover a longer period and permit a more complete study of the average flow.

These records give the average number of gallons pumped daily, as indicated by the revolutions of the engines. The actual quantities pumped are considerably less than the indicated amounts, owing to losses due to leakage or slip when the valves are not in perfect condition. The loss by slip depends upon the condition of the valves, and was very large a few years ago.

The valves were afterwards put in better order, and the slip is now much less.

The following table gives the average rate of flow per head per day for the first and last group of three years, in the decade from 1887 to 1897 : —

The Daily Average Rate of Flow per Capita at the Pumping Station of the Boston Main Drainage.

YEAR.	AVERAGE DAILY FLOW FOR EACH YEAR.			Estimated Gross Population, excluding Quincy.	Daily Average Rate per Capita.
	From Pump Records.	Estimated Slip.	After Deducting Estimated Slip.		
	Gallons.	Per Cent.	Gallons.		
1885, ...	33,874,575	–	–	–	–
1886, ...	36,866,129	–	–	–	–
1887, ...	43,630,657	30	30,500,000	274,000	111
1888, ...	52,937,143	30	37,000,000	293,000	126
1889, ...	51,211,198	30	35,700,000*	315,000	113
1890, ...	55,148,328	30	38,600,000*	–	–
1891, ...	63,749,891	30	44,600,000*	–	–
1892, ...	61,999,896	32	42,300,000*	–	–
1893, ...	72,835,209	23	56,400,000*	–	–
1894, ...	71,022,334	20	56,400,000*	–	–
1895, ...	75,625,215	18	62,300,000*	478,446	130
1896, ...	81,617,509	20	65,300,000	496,358	131
1897, ...	80,451,122	14	69,200,000	514,270	134

* Estimated by the street department.

According to the above figures, the daily average rate of flow per capita, based upon yearly periods, was about 113 gallons in 1889 and about 134 gallons in 1897. An extension of these rates to the year 1900 gives 144 gallons per head per day as the probable daily average flow in that year. This is nearly the same as the result derived from the measurements of the flow in the Charles River valley sewer in 1897, and indicates that the daily average flow of sewage from the entire district may be about 144 gallons per head per day in the year 1900.

An examination of the pumping records for 1897 at Old Harbor Point has been made, to ascertain to what extent the daily volume of sewage deviated from the yearly average during different parts of the year.

The yearly average is necessarily greater than the average flow during dry months, and less than the average flow during wet months. It includes the sewage derived from water supplies and manufacturing, the leakage from ground water and a portion of the storm water.

The average daily flow of each month, in 1897, exceeded the average for the year during four consecutive months at the beginning and two at the close of the year, which shows that the monthly average may be in excess during six consecutive months. The average daily flow during a wet week in each of seven different months was greater than the daily average of the year. The flow of the wettest day in each month was greater than the yearly average in every case but one; the greatest amount pumped in any single day during the year was about 50 per cent. more than the daily average for the year.

If provision were made to convey to the outlet an amount no greater than the average daily flow of the year, it is evident that large amounts of sewage would need to be discharged by overflows into local streams. Such overflows would be so frequent as to be considered objectionable. To avoid too frequent overflows, the amount to be conveyed to the outlet is taken at about 12 per cent. more than the daily average for the year, increasing it in 1897 from 134 to 150 gallons and in 1900 from 144 to 160 gallons per head per day. This is the quantity to be provided for in storage reservoirs. It is slightly more than the highest value of the average daily flow of the months, and represents approximately the maximum flow in dry weather. The above quantities do not include the rain water, which the intercepting sewers should convey to suitable points where it may overflow into tidal water.

The estimate of the amount of sewage to be provided for in the future during the years from 1900 to 1940 has been made from the estimated water supplies during this period.

The average daily consumption from 1850 to 1893 from the Cochituate and Mystic water works, and from 1880 to 1893 in the Boston metropolitan district, are given in Appendix No. 2 to the "Report of the Massachusetts State Board of Health on a Metropolitan Water Supply." The water consumption from 1893 to 1897 of the municipalities to constitute the south metropolitan sewerage district, has been obtained from this and other reports. From these data a prediction has been made of the probable water consumption in the south metropolitan sewerage district from 1900 to 1940. The result is a curved line, shown on the opposite diagram, giving an average water consumption of 100 gallons per head per day in 1900 and 140 gallons in 1940. This appears to conform closely to the law of increase in the rate of water consumption in this community in the past; and a comparison with the reported average daily water consumptions in some of the larger cities of the United States shows that these rates are not excessive.

Daily Consumption of Water, in Gallons per Capita, in Several of the Large Cities of the United States, compiled from Information received from the Metropolitan Water Board.

CITIES.	1884.	1886.	1888.	1890.	1892.	1894.	1897.
Boston, with Somerville, Chelsea and Everett, .	71	–	–	–	–	97	112
Metropolitan Water District, ...	65	–	–	–	–	89	102
New York, . . .	90	–	–	–	–	109	115
Chicago, ...	114	118	119	127	134	145	–
Philadelphia, . . .	74	80	100	132	143	173	215
Cincinnati, . . .	74	74	99	115	123	124	124
Cleveland, ...	83	91	95	106	118	130	127

The average daily water consumption is not identical with the average flow of ordinary sewage. Their equality is merely approximate. There is a portion of the public water supply which never reaches the sewers. On the other hand, there usually are private water supplies, a part of which is discharged into the sewers; and it is assumed that the sewage derived from these supplies equals the portion of the public supply which does not reach the sewers. The assumption is very nearly correct.

The flow of ordinary sewage varies from hour to hour. It is greatest during the hours when the most water is used. During dry weather the maximum flow from small districts is usually about 50 per cent. more than the yearly average hourly flow. This ratio becomes less if there is a large flow in the sewer derived from some constant source of supply, such as the infiltration of ground water. It is also less in a long intercepting sewer, such as the main sewer of the north metropolitan system and the proposed high-level sewer; because the increased flows,

although of normal amounts in the district sewers, occur at nearly the same time in the several towns, and enter the intercepting sewer at points widely separated. This increase of flow is found to be about 20 per cent. in the north metropolitan main sewer.

The water consumption during the coldest and warmest months is usually much greater than the average for the entire year. The increased consumption in winter is largely due to the waste of water during the night to prevent the freezing of pipes. This night consumption occurs when the flow of sewage is least in volume. The increased consumption in summer, however, occurs during the daytime, and combines with the larger flow of sewage to produce the maximum rate of flow during dry weather.

The following table gives the greatest monthly average consumption of water on the Cochituate works during the warm season in the years from 1890 to 1897, and a comparison with the average consumption of each year: —

YEAR.	Yearly Average Consumption (Gallons per Day).	Summer Month of Greatest Draught.	Monthly Average Consumption (Gallons per Day).	Per Cent. of Excess over Yearly Average.
1890, . . .	33,871,700	July, . . .	36,701,100	8
1891, . . .	37,686,900	September, . .	40,677,700	8
1892, . . .	41,312,400	July, . . .	45,738,100	11
1893, . . .	47,453,200	July, . . .	48,986,900	3
1894, . . .	46,560,000	July, . . .	50,044,000	7
1895, . . .	50,801,100	September, . .	53,246,900	5
1896, . . .	56,288,200	August, . .	57,215,700	2
1897, . . .	57,867,300	September, . .	60,980,600	5

The largest monthly average consumption during the warm season in this period is 11 per cent. more than the yearly average consumption of the same year. This is nearly the same as the allowance for the monthly fluctuation in the flow of sewage, which was fixed at about 12 per cent. more than the average of the year from the records of pumping at Old Harbor Point.

The maximum dry-weather flow of sewage in the year 1940 has been estimated approximately from the yearly average water supply of that year, which has been estimated from a study of the records of water consumption in this district.

Estimate of the Maximum Dry-weather Flow of Sewage in the Year 1940.

	Gallons per Head per Day.
Estimated yearly average water supply,	140
Add 12 per cent.,	17
Maximum monthly water supply,	157
Deduct for leakage from water pipes,	10
Maximum monthly average water consumption,	147
Add 20 per cent.,	29
Maximum hourly water consumption as sewage,	176
Leakage into sewers,	24
Maximum dry-weather flow of sewage,	200

The allowance for leakage into sewers in the above estimate is less than the rate of leakage as measured in some small districts in the north metropolitan system. It is also less than the rate of leakage estimated for the State Board of Health, and given in their "Report upon the Sewerage of the Mystic and Charles River Valleys" (Senate Document, No. 2, 1889). It is taken at a smaller rate partly because the high-level sewer is to be situated in high land, where it will be less exposed to the effects of tide water, and partly because the leakage in 1940 is likely to be less than that of earlier years, as some of the leaks will doubtless have been stopped before that time.

The yearly average flow of sewage from all sources in the year 1940 is taken at 175 gallons per head per day. The estimated yearly average flow, therefore, varies from 144 gallons in 1900 to 175 gallons in 1940.

The quantities to be used in determining the sizes of the high-level sewer are those given by the estimated flow of sewage during storms in 1940, the final year of the period for which the high-level sewer is designed.

It is expected that the greater part of the district tributary to the high-level sewer will be sewered by what is known as the separate system of sewerage, by which the greater part of the rainfall is diverted into the ordinary channels, leaving the sewage from dwellings and manufactories, the leakage from ground water and a small portion of rain water, to be conveyed in the sewers. Any draft of an act which may accompany this report should provide that the separate system of sewerage should be used in all distinctly new sewerage districts.

The allowance for rain water in the intercepting sewers of the Boston main drainage was equal to about 100 gallons per head per day, in addition to the maximum dry-weather flow of sewage.

An examination has been made of the records of the Boston main drainage works and the north metropolitan system, to ascertain the extent to which rain water affects the work of the pumps.

A comparison of the amount pumped at Old Harbor Point during the wettest month with the average for the year has been made for each year from 1885 to 1897. The pumping during the wettest month ranged from 5 per cent. to 45 per cent. more than the average of the year. The mean value was 30 per cent.

A similar comparison has been made for the year 1896–97 from the records of the pumping stations of the north metropolitan system, as given in the ninth annual report of the Board. They show that the average of the flows of the maximum day in each month was respectively 42, 44, 57 and 53 per cent. greater than the average flow of the year at the several pumping stations; the mean being 49 per cent. The flows of the maximum days during several of the wettest months were found to be in excess of the average flow of the year by the following percentages: Deer Island, 48 to 102; East Boston, 49 to 110; Charlestown, 66 to 114; Alewife Brook, 56 to 91.

It appears from this comparison that a mean of the flows of the maximum day in each month was about 50 per cent. more than the average flow of the year, and that the flow of some of the maximum days ranged from 48 per cent. to 114 per cent. more than the average flow of the year. The mean value is about 70 per cent. more than the yearly average. This rate would provide for all conditions except those of extremely wet weather. This increase of 70 per cent., when applied to the estimated yearly average flow of 1900, 144 gallons, gives about 244 gallons per head per day for the maximum storm flow in 1900, and when applied to the estimated yearly average flow of 1940, 175 gallons, gives about 300 gallons per head per day for the maximum storm flow of 1940. This latter rate is 100 gallons more than the estimated maximum dry-weather flow of sewage in 1940; an allowance nearly identical with that used for the Boston main drainage.

Recapitulation.

The rates per capita determined for the high-level sewer by this study are as follows: —

	GALLONS PER HEAD PER DAY.	
	1900.	1940.
Yearly average water supply, ...	100	140
Yearly average flow of sewage, ...	144	175
Maximum dry-weather flow of sewage, . . .	160	200
Maximum flow during storms, ...	244	300

These rates of flow for the year 1940 are somewhat larger than those used in determining the sizes of the Boston main drainage works. The estimate for the maximum rate of flow made in 1877 for the main intercepting sewer was about 154,000,000 gallons per day for a prospective population of 600,000 persons, or 257 gallons per head per day. This was based upon an average rate of water consumption of 75 gallons per head per day, which was doubled to represent the maximum rate, to which was added an allowance for storm water equal to about 100 gallons per head per day. An estimate for the maximum flow, made in 1875, gave about 280,000,000 gallons for a prospective population of 1,000,000 persons tributary to the outfall sewer, or at the rate of 280 gallons per head per day.

The amount now proposed, 300 gallons per head per day, is based upon an estimated average daily water consumption in 1940 of 140 gallons per head per day, which is increased to 200 gallons for the maximum dry-weather flow of sewage in that year. This is equivalent to an allowance of only 60 gallons per head per day for fluctuations in hourly flows, infiltration of ground water and all other contingent sources of supply. To this is added an allowance of 100 gallons per head per day for storm water, and possible increase in the contributary territory.

The Quantity of Sewage.

The daily volume of sewage based upon the foregoing rates of flow and upon the estimated population that would be tributary to the Boston main drainage if the sewerage systems now connected with it were extended over their entire districts, is given in the following table: —

Table showing Estimated Average and Maximum Flows of Sewage, from 1900 to 1940, from the Boston Main Drainage and South Metropolitan Districts, combined, including Quincy.

Year.	Estimated Population.	Daily Flow — The Rate being considered Uniform throughout the Twenty-four Hours.					
		Yearly Average Flow.		Maximum Dry-Weather Flow.		Maximum Flow, including an Allowance for Storm Water.	
		Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.
			Gallons.		Gallons.		Gallons.
1900,	603,906	144	86,962,464	160	96,624,960	244	147,353,064
1905,	682,845	147	100,378,215	165	112,669,425	251	171,394,095
1910,	774,292	151	116,918,092	170	131,629,640	258	199,767,336
1915,	873,300	155	135,361,500	175	152,827,500	265	231,424,500
1920,	984,900	159	156,599,100	180	177,282,000	272	267,892,800
1925,	1,111,600	163	181,190,800	185	205,646,000	279	310,157,400
1930,	1,248,800	167	208,549,600	190	237,272,000	286	357,176,800
1935,	1,395,000	171	238,545,000	195	272,025,000	293	408,735,000
1940,	1,550,000	175	271,250,000	200	310,000,000	300	465,000,000

The quantities to be conveyed by the intercepting sewers, pumping station, and tunnel of the Boston main drainage would be somewhat less because the sewage of Quincy would enter the system at Squantum beyond the tunnel. These quantities are given in the following table and the diagram facing page 46: —

Table showing Estimated Average and Maximum Flows of Sewage, from 1900 to 1940, from the Boston Main Drainage and South Metropolitan Districts, combined, but not including Quincy.

Year.	Estimated Population.	Daily Flow — the Rate being considered Uniform throughout the Twenty-four Hours.					
		Yearly Average Flow.		Maximum Dry-Weather Flow.		Maximum Flow, including an Allowance for Storm Water.	
		Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.
			Gallons.		Gallons.		Gallons.
1900,	578,006	144	83,232,864	160	92,480,960	244	141,033,464
1905,	650,445	147	95,615,415	165	107,323,425	251	163,261,695
1910,	733,792	151	110,802,592	170	124,744,640	258	189,317,800
1915,	823,500	155	127,642,500	175	144,112,500	265	218,227,500
1920,	926,100	159	147,249,900	180	166,698,000	272	251,899,200
1925,	1,042,800	163	169,976,400	185	192,918,600	279	290,941,200
1930,	1,169,400	167	195,289,800	190	222,186,000	286	334,448,400
1935,	1,305,000	171	223,155,000	195	254,475,000	293	382,365,000
1840,	1,450,000	175	253,750,000	200	290,000,000	300	435,000,000

The carrying capacity of the tunnel under Dorchester Bay already been given as about 122,000,000 gallons per twenty-1 hours for continuous service, under the present methods of op ating the works. The above table and accompanying diagn show that the allowance here made for the maximum flow du ing storms is already greater than the above quantity, and th the continuous working capacity of the Boston main drainag is already exceeded during heavy and long-continued storms.

This conclusion is confirmed by the action of the Charles River valley metropolitan sewer, which discharges into the main intercepting sewer of the Boston main drainage. The Boston sewers during heavy rains become surcharged and unable to receive the sewage from the Charles River valley which then has to overflow into Charles River for considerable periods.

The estimated capacity of the Boston main drainage works, after some modifications have been made in them, has already been given as about 154,000,000 gallons per twenty-four hours. The foregoing table shows that provision for this quantity should be made before 1903; but the reduction of the area tributary to the Boston main drainage works which would result from the construction of the high-level sewer would put off the time when the full capacity of these works would be attained.

The following extracts from the annual report of the street department of the city of Boston for the year 1896, show that those in charge of the sewer division are already aware of the necessity of providing an early relief for the pumping system of the Boston main drainage: —

> It has always been considered a part of the scheme for intercepting the sewers of Boston that a "high-level" sewer would be built which would intercept the sewage from the high streets in the interior of the suburbs, and carry it direct by gravity to Moon Island without the expense of pumping it up. (Report Street Department, 1896, page 329.)
>
> The city should proceed with the designing and constructing of what is known as the high-level sewers, which were advocated at the time that this plant was put in, so as to relieve the pumps. (Report Street Department, 1896, page 363.)

It might be several years before the high-level sewer would be completed and in operation; but it is desirable that the

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relief to be afforded by it should be obtained at the earliest time practicable, as thereby the necessity for making extensive modifications to the Boston main drainage works would be deferred for some years.

The High-level and Low-level Districts.

In apportioning the districts which should be tributary respectively to the high-level sewer and the main drainage pumping system, it should be kept in mind that the capacity of the latter is already fixed, and that its tributary district should be limited to an area which would contribute an amount of storm sewage about equal to this capacity at the end of the period which is here considered.

The apportionment which first suggests itself is to give to the high-level sewer all the territory from which the sewage can reach it by gravity, and to leave tributary to the pumping station of the Boston main drainage at Old Harbor Point all the lower districts except the one in Quincy, which is now tributary to the outfall sewer.

The populations and volume of flow of sewage arising from this apportionment are given in the following table: —

Table showing Estimated Average and Maximum Flows of Sewage from 1900 to 1940 from All the Low Districts except that of Quincy.

[These districts are here considered as tributary to the Boston main drainage pumping station at Old Harbor Point.]

YEAR.	Estimated Population.	Daily Flow — the Rate being considered Uniform throughout the Twenty-four Hours.					
		Yearly Average Flow.		Maximum Dry-weather Flow.		Maximum Flow, including an Allowance for Storm Water.	
		Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.
			Gallons.		Gallons.		Gallons.
1900,	463,606	144	66,759,264	160	74,176,960	244	113,119,864
1905,	506,345	147	74,432,715	165	83,546,925	251	127,092,595
1910,	554,792	151	83,773,592	170	94,314,640	258	143,136,336
1915,	603,200	155	93,496,000	175	105,560,000	265	159,848,000
1920,	656,800	159	104,431,200	180	118,224,000	272	178,649,600
1925,	719,100	163	117,213,300	185	133,033,500	279	200,628,900
1930,	784,100	167	130,944,700	190	148,979,000	286	224,242,600
1935,	851,000	171	145,521,000	195	165,945,000	293	249,343,000
1940,	928,000	175	162,400,000	200	185,600,000	300	278,400,000

The entrance of storm water into the intercepting sewers of the Boston main drainage is generally controlled by automatic regulators; but there are several districts, comprising an area of about 245 acres, in which the regulators were omitted to give relief from the flooding of cellars when heavy rainfalls occurred at or near the time of high tide. The large amount of storm water that is allowed to enter the main drainage sewers from these districts reduces the amount that may enter from other districts, and during heavy rainfalls may itself be larger than the quantity of storm water expected to enter the main intercepting sewer from the entire district. The effect of this is to gorge the main sewer, overload the pumps, and interfere with the proper working of the system for many hours after a storm has ceased.

If this practice were abandoned and the amount of storm sewage were reduced to the amounts here estimated, the final safe working capacity of the pumping system, 154,000,000 gallons per twenty-four hours, might not be attained until the year 1913. This restricted storm flow, however, would amount to about 278,400,000 gallons per twenty-four hours in 1940, which exceeds the limiting capacity of the works. It is therefore evident that the pumping system cannot permanently receive the sewage from all the low districts. The sewage from some of these districts must therefore be raised to another outlet. That most conveniently attainable is the high-level sewer itself.

The district recommended to remain tributary to the pumping station at Old Harbor Point embraces Boston proper, South Boston and territory in Roxbury, West Roxbury and Dorchester. It is composed of the low districts of Boston which are not now tributary to the existing metropolitan sewers, and has an area of about 12 square miles.

The district recommended to be tributary ultimately to the high-level sewer comprises the area from which sewage would reach that sewer by gravity and also the lower areas now tributary to the Charles River valley and the Neponset valley sewers. The sewage from these will have to be pumped to the high-level sewer. It also includes the city of Quincy. Its area is about 109 square miles.

These districts are shown on Plate No. 3. The territory remaining tributary to the pumping station of the Boston main drainage is shown by the buff tint. The districts from which sewage can be received by gravity into the high-level sewer are shown by the green tint. Those from which the sewage must be pumped to the high-level sewer are shown by the blue tint. The heavy red line from Moon Island to Brookline shows one of the suggested routes for the high-level sewer. Its extension to Newton is shown by the dotted red line. The metropolitan sewers in the valleys of the Charles and Neponset rivers are shown by the broken red lines. The intercepting sewers, tunnel and outfall sewers of the Boston main drainage are shown by the broken brown lines.

A district in West Roxbury and the irregularly shaped district in Roxbury and Dorchester, colored green, are to be withdrawn from the area now tributary directly to the Boston main drainage, and are to be made tributary to the high-level sewer. The proposed pumping stations in Boston and Quincy and the force mains from them to the high-level sewer are shown by dark-blue lines.

Population.

The estimated future populations upon the districts to be tributary to the high-level sewer and also those upon the districts to remain tributary to the pumping station of the Boston main drainage at Old Harbor Point are given in the following table for every fifth year from 1900 to 1940. The population of the district to be tributary to the high-level sewer is estimated at 250,400 in 1900 and 986,000 in 1940.

Estimated Populations upon the Districts to be Tributary to the High-level Sewer either by Gravity or by Pumping; also Populations upon the Districts to remain Tributary to the Boston Main Drainage Pumping Station at Old Harbor Point.

[The former includes the high gravity area, the low area tributary to the Charles and Neponset metropolitan systems and also Quincy; the latter includes the low districts of Boston not now tributary to the existing metropolitan sewers.]

CITIES AND TOWNS.	POPULATIONS.																	
	1900.		1905.		1910.		1915.		1920.		1925.		1930.		1935.		1940.	
	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.	High-level Sewer.	Old Harbor Point.
Waltham,	23,600	-	28,300	-	34,000	-	40,800	-	49,000	-	58,800	-	69,000	-	79,000	-	89,000	-
Watertown,	9,300	-	11,200	-	13,400	-	16,100	-	19,300	-	23,300	-	28,100	-	33,000	-	37,000	-
Newton,	33,700	-	41,100	-	50,100	-	60,600	-	71,500	-	83,500	-	96,000	-	108,000	-	119,000	-
Brighton,	19,500	-	24,500	-	30,700	-	38,200	-	47,100	-	57,100	-	68,000	-	80,000	-	93,000	-
Brookline,	20,200	-	25,000	-	31,000	-	38,400	-	47,400	-	58,000	-	70,000	-	81,000	-	92,000	-
Back Bay District,	14,000	-	17,000	-	21,000	-	25,000	-	29,000	-	34,000	-	39,000	-	44,000	-	50,000	-
West Roxbury,	32,700	10,000	42,100	12,500	53,500	15,000	66,500	17,500	80,800	20,000	97,000	22,500	114,000	25,000	133,500	27,500	155,000	30,000
Dedham,	8,000	-	9,500	-	12,000	-	16,000	-	21,000	-	27,000	-	34,000	-	42,000	-	50,000	-
Hyde Park,	14,100	-	16,600	-	19,600	-	23,300	-	28,000	-	34,000	-	41,500	-	50,000	-	58,000	-
Milton,	6,900	-	8,600	-	10,700	-	13,300	-	16,200	-	19,700	-	23,800	-	29,000	-	35,000	-
Roxbury and Dorchester,	42,500	120,000	49,100	140,000	56,300	160,000	62,400	180,000	70,600	200,000	77,800	224,000	87,000	248,000	96,500	276,000	108,000	310,000
Boston proper and South Boston, less Back Bay,	-	223,506	-	224,945	-	226,492	-	225,400	-	226,200	-	226,100	-	226,000	-	225,500	-	224,000
Quincy,	25,900	-	32,400	-	40,500	-	49,800	-	58,800	-	68,800	-	79,400	-	90,000	-	100,000	-
	250,400	353,506	305,400	377,445	372,800	401,492	450,400	422,900	538,700	446,200	639,000	472,600	749,800	499,000	866,000	529,000	986,000	564,000
	603,906		682,845		774,292		873,300		984,900		1,111,600		1,248,800		1,395,000		1,550,000	

Volume of Sewage.

The anticipated daily volumes of sewage to be conveyed to the Boston main drainage pumping station are given in the following table for every fifth year from 1900 to 1940, based upon the rates of flow per capita already determined, and upon the populations given in the preceding table for the districts to be tributary to this pumping station.

Table showing Estimated Average and Maximum Flows of Sewage, from 1900 to 1940, to be conveyed to the Pumping Station of the Boston Main Drainage.

[The district includes the low portions of Boston which are not now tributary to the existing metropolitan sewers.]

YEAR.	Estimated Population.	DAILY FLOW—THE RATE BEING CONSIDERED UNIFORM THROUGHOUT THE TWENTY-FOUR HOURS.					
		YEARLY AVERAGE FLOW.		MAXIMUM DRY-WEATHER FLOW.		MAXIMUM FLOW, INCLUDING AN ALLOWANCE FOR STORM WATER.	
		Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.
			Gallons.		Gallons.		Gallons.
1900,	353,506	144	50,904,864	160	56,560,960	244	86,255,464
1905,	377,445	147	55,484,415	165	62,278,425	251	94,738,695
1910,	401,492	151	60,625,292	170	68,253,640	258	103,584,936
1915,	422,900	155	65,549,500	175	74,007,500	265	112,068,500
1920,	446,200	159	70,945,800	180	80,316,000	272	121,366,400
1925,	472,600	163	77,033,800	185	87,431,000	279	131,855,400
1930,	499,000	167	83,333,000	190	94,810,000	286	142,714,000
1935,	529,000	171	90,459,000	195	103,155,000	293	154,997,000
1940,	564,000	175	98,700,000	200	112,800,000	300	169,200,000

The relations between these volumes of sewage and the capacity of the Boston main drainage pumping system are shown on the diagram facing page 52.

The maximum flow, including an allowance for storm water from these districts, may attain the maximum capacity of the system, 154,000,000 gallons per twenty-four hours, about the year 1934, and a slight curtailment of the amount of storm water admitted may be necessary after that year.

The capacity of the enlarged reservoir, about 44,000,000 gallons when filled to "grade 22," may be sufficient for this storm flow until about 1911, if a storage of ten hours between tides can be maintained. If it is filled to a capacity of 50,000,000 gallons, equivalent to a flow of 120,000,000 gallons per twenty-four hours, with ten hours' storage between tides, it may be sufficient until about 1920, if the whole allowance of storm water is taken to Moon Island. But, if the quantity conveyed should be limited to the maximum dry-weather flow, this reservoir capacity might suffice until about the end of the period. Greater reservoir capacity could be had when needed by building another reservoir at Moon Island.

The volumes of sewage to be conveyed by the high-level sewer, estimated from the before-mentioned rates of flow per capita and the populations given in the table for the tributary districts, are given in the following table for every fifth year from 1900 to 1940: —

Table showing Estimated Average and Maximum Flows of Sewage, from 1900 to 1940, to be conveyed by the High-level Sewer.

[The district includes the high gravity area, the low areas now tributary to the Charles and Neponset metropolitan systems, and also Quincy.]

YEAR.	Estimated Population.	DAILY FLOW — THE RATE BEING CONSIDERED UNIFORM THROUGHOUT THE TWENTY-FOUR HOURS.					
		YEARLY AVERAGE FLOW.		MAXIMUM DRY-WEATHER FLOW.		MAXIMUM FLOW, INCLUDING AN ALLOWANCE FOR STORM WATER.	
		Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.	Per Head per Day.	Daily Volume.
			Gallons.		Gallons.		Gallons.
1900,	250,400	144	36,057,600	160	40,064,000	244	61,097,600
1905,	305,400	147	44,893,800	165	50,391,000	251	76,655,400
1910,	372,800	151	56,292,800	170	63,376,000	258	96,182,400
1915,	450,400	155	69,812,000	175	78,820,000	265	119,356,000
1920,	538,700	159	85,653,300	180	96,966,000	272	146,526,400
1925,	639,000	163	104,157,000	185	118,215,000	279	178,281,000
1930,	749,800	167	125,216,600	190	142,462,000	286	214,442,800
1935,	866,000	171	148,086,000	195	168,870,000	293	253,738,000
1940,	986,000	175	172,550,000	200	197,200,000	300	295,800,000

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1935,	8
1940,	9

THE HIGH-LEVEL SEWER, SUGGESTED ROUTES AND ESTIMATED COSTS.

Route to Moon Island.

It has been shown, in the foregoing description of the Boston main drainage works, that the district intended to be tributary to them has been very greatly enlarged; also, that the population in this district has been increasing rapidly, and that a somewhat more liberal rate of flow per capita than was used to fix the capacity of the Boston main drainage works should now be used in determining the capacity of the south metropolitan system.

It was intended that the outfall of those works should eventually receive the sewage from a high-level sewer. Considered as an independent structure, the outfall sewer has a carrying capacity estimated at about 320,000,000 gallons per twenty-four hours. The estimated total quantities of sewage flowing from the Boston main drainage and south metropolitan districts, including an allowance for storm water, are given in the first table on page 45. It is there shown that the maximum flow may amount to 465,000,000 gallons per twenty-four hours in the year 1940, of which 295,800,000 gallons should be carried by a high-level sewer. The total is about 45 per cent. more than the carrying capacity of the outfall sewer of the Boston main drainage, if it were flowing full.

This may be stated in another way. The carrying capacity of the Boston outfall sewer from Moon Island to Squantum when flowing full being about 320,000,000 gallons per twenty-four hours, and the carrying capacity of the present intercepting sewer being 154,000,000 gallons, the outfall sewer could receive 166,000,000 gallons, or only 56 per cent. of the estimated maximum flow of the high-level sewer. The estimated maximum flow of the high-level sewer in 1940 being about 296,000,000 gallons, if a connection with the Boston outfall sewer should be made, it would still be necessary to provide another outfall sewer, having a carrying capacity of about 130,000,000 gallons per twenty-four hours.

Thus it is evident that a supplementary outfall for the high-level system would be needed long before the expiration of the period for which that system is designed, if the high and low systems were combined at the outfall sewer of the Boston main drainage. It is therefore necessary to consider the practicability and cost of establishing a supplementary or independent reservoir and outfall at Moon Island for the high-level sewer.

The area of Moon Island above high water is about 35 acres. About one-third of this area in the middle of this island is covered by the present reservoir and its extension. The high land at the east end of the island might be graded to a level of about 25 feet above low water. This would provide a site of about 20 acres for a reservoir of about 80,000,000 gallons capacity. The shallow water west of the present reservoir might be filled with earth from the hill. This, with 4 acres of land in that vicinity, would provide a site for a small reservoir of about 20,000,000 gallons capacity, but its cost would be relatively great.

If the whole island were used for reservoirs, an aggregate storage capacity of about 130,000,000 gallons might be obtained, with the possibility of increasing it to about 150,000,000 gallons by constructing a small reservoir partly on filled land. A storage of 130,000,000 gallons during ten hours of each tide would provide for a flow of 312,000,000 gallons per twenty-four hours; and a storage of 150,000,000 gallons during ten hours of each tide would provide for a flow of 360,000,000 gallons per twenty-four hours. The maximum dry-weather flow from the combined districts might not attain these volumes until after the year 1940.

The existing embankment from Squantum to Moon Island in which the outfall sewer was built was filled on a deep bed of mud, and has now reached a state of equilibrium. It is not wide enough for another large sewer. To widen it might destroy its present equilibrium, and cause a fracture of the existing outfall sewer.

To construct two sewers, one at Squantum from the high-level sewer to the existing outfall sewer to convey 166,000,000 gallons to the Boston outfall, and one from Squantum to Moon Island to convey 130,000,000 gallons, would cost about $100,000 more than to build one large sewer from Squantum to Moon Island having a carrying capacity equal to both.

If the reservoir and outfall were independent of the Boston system, the former could be set so that its level when full would be 22 feet above low water. The elevation of the flow line in the high-level sewer would then be about 3.4 feet lower than it would be if a connection were made with the Boston outfall. The lift of the pumps at the Boston pumping station would be about 3 feet less in 1940 if the high-level sewer were given an independent outfall.

As before stated, a site for a reservoir of 80,000,000 gallons capacity could be obtained at Moon Island for the high-level sewer by grading the hill at the easterly end of the island. A reservoir with a storage capacity of 40,000,000 gallons when filled to "grade 22" would provide for a daily flow of 96,000,000 gallons per twenty-four hours when storing ten hours between tides This might receive the maximum dry-weather flow of the high-level sewer until about 1920, when an extension of the reservoir to 80,000,000 gallons capacity could be made. New discharge channels, capable of discharging 80,000,000 gallons in one hour, could be built.

The material excavated from the hill and the reservoir could be used to form the embankment for a new outfall sewer from Squantum, with a capacity of 296,000,000 gallons per twenty-four hours. This embankment would be filled over a route about 1,200 feet south of the present embankment, and would pass over a half-tide bar known as Little Moon Island. The sides of the embankment would be protected with stone, and culverts would be provided in it to prevent confining the sea water between the two embankments.

The sewage would be screened at the reservoir, to remove any large floating or suspended substances; but no attempt would be made to take out the heavier portions of the sewage, as is now done at the deposit sewers at Old Harbor Point.

The greater portion of the high-level district is situated west of the Stony Brook valley, and above Hyde Park in the Neponset valley. The shortest route for a main sewer from Squantum to this territory is a direct line to a point on the west side of Stony Brook, about a mile south of Forest Hills station.

A main sewer would divide above this point one branch going south to intercept the Neponset valley sewer in Hyde Park near Mattapan Mills, the other going north, following along the Stony Brook valley, passing through the Muddy Brook divide near Jamaica Pond to the corner of Catalpa and Castleton streets in West Roxbury, where a branch sewer leading to the force main from the Charles River valley sewer would enter the main sewer.

If this route were followed, the high-level sewer would be built in embankment across the marshes to the Neponset River. It would pass under the river by a pipe siphon at Ericson Street, about half a mile south of Commercial Point. This siphon would be about a mile in length, and for protection would need a sand-catcher, which would necessarily be placed in a thickly settled locality in Dorchester. This route passes directly across the high land in Dorchester, and the sewer would need to be in a deep tunnel about 2 miles in length before reaching Stony Brook valley.

The sewer by this route would reach the vicinity of Forest Hills about 4.5 feet lower than by any of the other routes examined. It would permit about 1 square mile more of territory to be sewered by gravity, and would provide for the sewage of about 10,000 more people. On the other hand, this route would cost about $400,000 more than the route shown on Plate No. 3. The excess in cost, the long siphon from a thickly settled district in Dorchester, and the very long tunnel to the Stony Brook valley, make this route less desirable than the other routes.

Several different routes from Squantum have been examined in detail; one crossing the river by a siphon at Neponset Avenue near the bridge, and others in tunnel through the Milton Hill to the Unkety Brook valley.

The route leading to Moon Island which was found on the whole to be least expensive and most desirable is shown on Plate No. 3.

This route diverges from the one first described near Moswetussett Hill in Quincy, and passes through the villages of Atlantic and Montclair in Quincy to East Milton; thence through the valleys of Unkety and Pine Tree brooks to the easterly part of Hyde Park in the Neponset River valley, where the existing Neponset valley sewer would be intercepted; thence through the divide at Clarendon Hills to the Stony Brook valley. The route then resumes the location first described on the west side of Stony Brook, passes near Jamaica Pond to the point in West Roxbury where it is to receive the sewage from a branch sewer leading to the main from the Charles River valley sewer.

The high-level sewer, if this route were followed, would begin at Moon Island, with a horse-shoe section having interior diameters of 11 feet 4 inches by 12 feet, and with the invert at elevation 111.86 feet above the metropolitan sewerage datum, which is about 100 feet below low water. This size would continue to a point near Atlantic station, rising at the rate of 1 foot in 3,500 feet and attaining an elevation of 116.55.

The sewer would cross the depression formed by the marshes near Atlantic by means of a siphon about 2,500 feet in length. This siphon would be formed of parallel lines of cast-iron pipes, 5 feet in diameter internally. Two of these lines would be laid at first. The head house at each end of the siphon would be built so that the number of lines of pipes could be increased in the future.

At the southerly end of the siphon the sewer would resume its usual shape, with internal diameters of 10 feet 10 inches by 11 feet 6 inches at elevation 117.23, rising at the rate of 1 foot in 3,500 feet. It would be in tunnel for some 1,200 feet near Harvard Street. At Adams Street its elevation would be 119.28 feet above datum. It would then be reduced to 10 feet 8 inches by 11 feet 4 inches, which size would continue to Randolph Avenue, where its elevation would be 121.25. Here it would be reduced to 10 feet 7 inches by 11 feet 2 inches. This size would continue to East River Street in Hyde Park, except for a distance of about 110 feet at the crossing of the Neponset River, which would consist of lines of cast-iron pipe, 4 feet 6 inches in diameter. Two lines would be needed at first. The head houses at the ends of the river crossing would be built so that the number of pipes could be increased. This crossing would not be a siphon, as there would be no depression made in the invert of the sewer.

At East River Street the existing Neponset valley sewer would be intercepted, and the sewage from parts of Newton, Brookline, West Roxbury, Dedham and Hyde Park would be admitted to the high-level sewer. The elevation of the sewer here would be 124.09.

Above East River Street the sewer would be reduced to 9 feet 3 inches by 9 feet 9 inches. This size would continue to the line between Hyde Park and West Roxbury. The sewer would pass through the divide between the Neponset River and Stony Brook valleys by a tunnel about 4,500 feet long. Its elevation at the West Roxbury line would be 126.13.

In West Roxbury the diameter would be 8 feet 10 inches by 9 feet 4 inches. This size would continue to near the junction of South and Centre streets, and would be in tunnel for about 1,750 feet. The elevation at Centre and South streets would be 129.98.

Beyond Centre and South streets the size of the sewer would be 8 feet 3 inches by 8 feet 9 inches. It would pass through Centre Street, private land in line of projected streets, and Catalpa Street, by a deep tunnel about 5,352 feet long to the junction of Catalpa and Castleton streets, where its elevation would be 131.51. Here the high-level sewer would receive the sewage of the Charles River valley sewer, which would be pumped at a station on Huntington Avenue, near Longwood Avenue, Boston.

The slope of the high-level sewer to this point has been taken at 1 foot in 3,500 feet, except at the siphon in Quincy near Atlantic. The volume of flow will be considerably less above the point where the sewage from the Charles River valley sewer would be received, and smaller sizes with steeper gradients will be used when the high-level sewer is extended into the upper parts of the valley.

The route of the high-level sewer above the point where the sewage from the Charles River sewer would be received has not been examined with as much exactness as the route below that point, since it appears probable that it may be a number of years before that portion of the high-level sewer would be constructed. A route which appears to be suitable and practicable has, however, been shown on Plate No. 3.

This crosses Muddy River a short distance below Jamaica Pond, by means of a siphon of cast-iron pipes, the elevation of the upper end of which would be about 133.5. The line would enter Brookline and follow substantially the route shown on the plate to the boundary between Brookline and Brighton, where the elevation of the sewer would be about 137.7.

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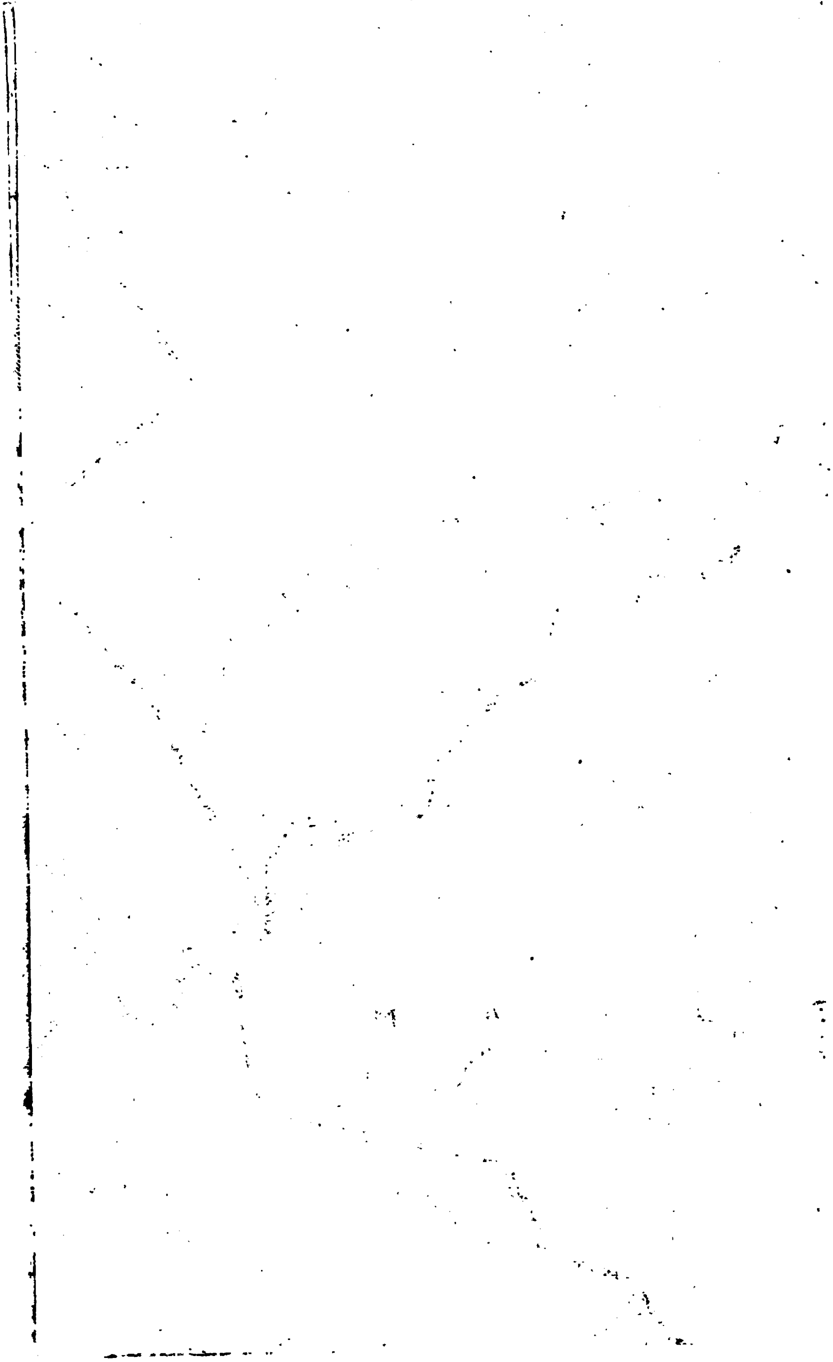

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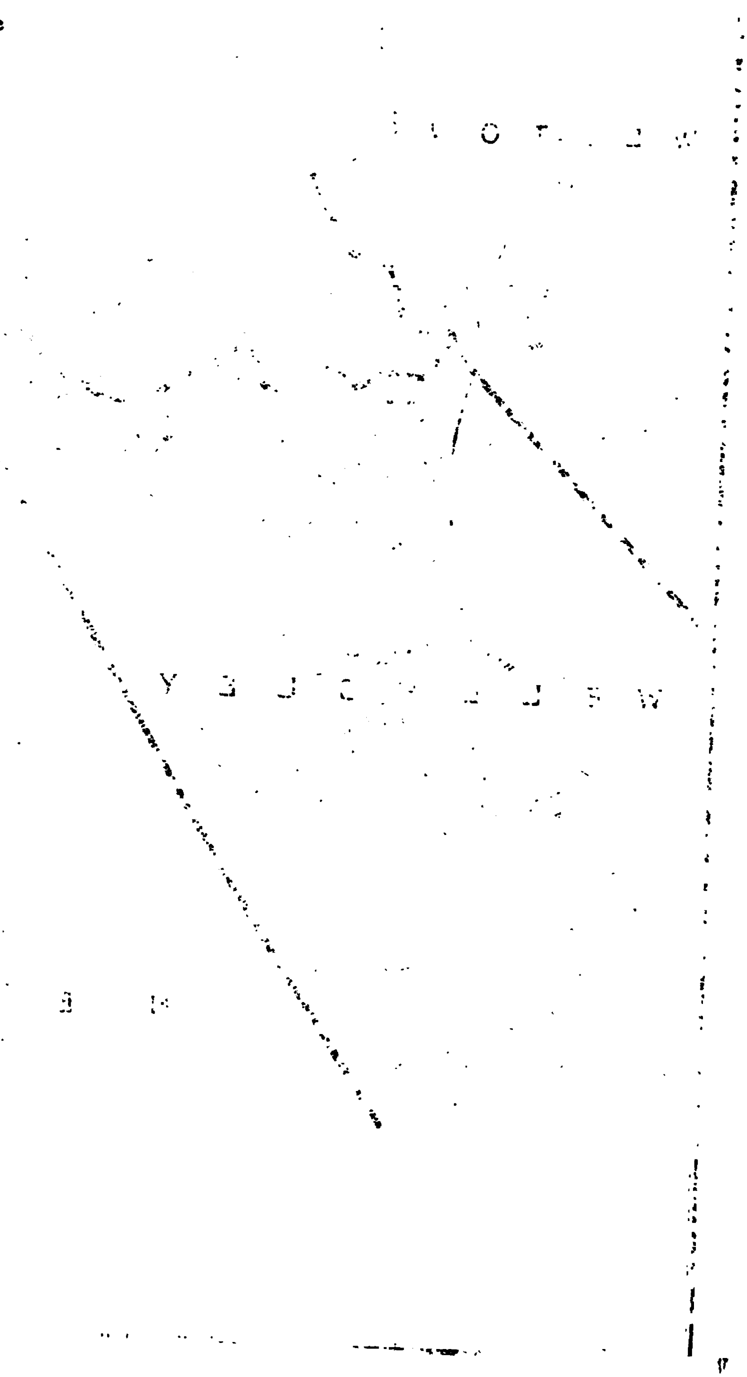

The sewer would have an internal diameter of 6 feet, and an inclination of 1 foot in 3,000 feet from the end of the siphon near Jamaica Pond to the boundary line between Brighton and Brookline.

The line would continue in Brighton, following substantially the route shown on the plate, to the boundary line between Brighton and Newton at Tremont Street, where the elevation of the sewer would be about 143.0. A branch 4 feet in diameter would be left at this place for future extensions into Newton. The sewer through Brighton would have an internal diameter of 5 feet and an inclination of 1 foot in 2,500 feet.

Estimate of Cost.

The following is an estimate of the cost of constructing the high-level sewer by this route from Moon Island to the junction of Castleton and Catalpa streets in West Roxbury: —

Estimated Cost of High-level Sewer from Moon Island to Junction of Castleton and Catalpa Streets, West Roxbury.

SECTION.	Diameter of Sewer.	Length of Section (Feet).	Cost.	Remarks.
Construction on Moon Island, including outlet and discharge sewers, reservoir (40,000,000 gallon capacity) and outfall sewer.	10' 10"×12' and 11' 4"×12',	1,500	$942,365	Earth excavation, includes grading roadways, improving shore line, embankment between Moon Island and Squantum.
Main sewer in embankment from Moon Island to Squantum.	11' 4"×12', ...	5,250	424,525	Includes four tidal culverts through embankment.
In private land (marsh and upland) North, Atlantic and Billings streets, to the lower head house of siphon near Atlantic station, Quincy.	11' 4"×12', ...	10,720	560,970	Earth excavation for 3,220 linear feet, sewer in embankment and on pile foundation for 4,000 linear feet, earth and rock excavation for 3,500 linear feet.
Siphon and two head houses in private land (marsh and upland), Sagamore and Hancock streets.	60" pipes, ...	2,560	99,804	Head houses for 60-inch cast-iron pipe, two lines to be laid at first for siphon.
In private land (marsh and upland), Sterling, Sagamore, Revere and Eliot streets, to a point in Adams Street, 600 feet west of the East Milton station.	10' 10"×11' 6", ...	7,159	285,733	Sewer in embankment and on pile foundation for 470 linear feet, earth tunnel for 1,150 feet, earth excavation in open trench for 5,539 linear feet.
In private land to a point in Randolph Avenue, Milton, about 1,100 feet north of Centre Street.	10' 8"×11' 4", ...	6,907	207,210	Earth excavation.
In private land, Canton Avenue, Brook Road and Mattakeeset Street, to East River Street, Hyde Park.	10' 7"×11' 2", ...	9,917	389,696	Includes Neponset River crossing, head houses, tunnel in rock for 1,100 linear feet, earth and rock cut for 700 linear feet, open earth cut for 7,921 linear feet, Neponset River crossing, 196 linear feet.
In private land, Ralston and Ruskin roads, to the boundary line between Hyde Park and West Roxbury.	9' 3"×9' 9", ...	7,163	337,665	Includes Stony Brook crossing, head houses, tunnel in rock for 4,500 linear feet, excavation in earth and rock for 897 linear feet, excavation in earth for 1,690 linear feet, Stony Brook crossing, 76 linear feet.
In private land, Hammatt Road and Hadwin Way, Hyde Park Avenue, Larch Place, Harrison Street, Arborway and South Street in West Roxbury to Centre Street.	8' 10× 9' 4", ...	13,478	386,656	Two brook crossings, under sewer, excavation in earth tunnel for 1,824 linear feet, excavation in open earth cut for 5,884 linear feet, excavation in earth and rock cut for 800 linear feet, excavation in earth cut and embankment for 3,920 linear feet, excavation in earth cut and pile foundation for 1,050 linear feet.
In private land, Centre Street and Catalpa Street, to Castleton Street.	8' 3"×8' 9", ...	5,352	251,287	Excavation in earth tunnel for 1,156 linear feet, excavation in rock tunnel for 4,196 linear feet.
Total, ...			$3,885,911	
Engineering and contingencies, 15 per cent., ...			582,887	
Total cost of construction, ...			$4,468,798	
Rights of way, ...			176,600	
Total cost of main sewer, ...			$4,645,398	

It has been shown in the study of the district tributary to the Boston main drainage that the pumping system cannot permanently receive the sewage from all the low districts, and that the sewage from some of these districts must be raised to another outlet, the high-level sewer itself being the one most conveniently attainable.

There are two districts from which sewage will need to be raised to the high-level sewer. The larger consists of the territory tributary to the Charles River metropolitan sewer, and has an area of about 28.6 square miles.

This sewer now discharges into the main intercepting sewer of the Boston main drainage. It is proposed to abandon this connection and to reverse the slope of the Charles River valley sewer between Gainsborough and Ruggles streets, making the latter the lowest point in the sewer. From this point a new sewer, 6 feet 6 inches in diameter, would be built to convey the sewage of the Charles River metropolitan district to a pumping station near the corner of Huntington and Longwood avenues. The sewage would here be lifted about 40 feet, and pumped through force mains consisting of 2 lines of 48-inch cast-iron pipes, following Huntington and South Huntington avenues to a point near the corner of Heath Street. This would be the highest point in the forcing main. A gravity sewer, 6 feet 6 inches in diameter, constructed in tunnel, would convey the sewage from this summit to the corner of Castleton and Catalpa streets, where a connection with the high-level sewer would be made.

Estimate of Cost.

The following is an estimate of the cost of the pumping station, forcing main, sewers and other work required for the works to raise the sewage of the Charles River valley to the high-level sewer: —

Estimated Cost of Pumping Station and Forcing Main for Charles River Valley Sewer.

Reversing grade of Charles River valley sewer in Huntington Avenue below Ruggles Street, ...	$4,300
1,350 linear feet 6 feet 6 inches sewer from Charles River valley sewer at Ruggles Street to pumping station, cost, plus 15 per cent., ...	39,516
Pumping station, site and pumping plant, ...	272,000

Two lines 48-inch forcing main, 4,550 linear feet, at $29.50, plus 15 per cent.,	$154,359
2,455 linear feet 6 feet 6 inches sewer, from upper end of forcing mains to high-level sewer, cost, plus 15 per cent.,	78,565
Total,	$548,740

The smaller district from which sewage may eventually be raised to the high-level sewer consists of low areas in Dorchester and Milton, between Hyde Park and Granite bridge, comprising about 3.8 square miles. These areas are tributary to the Neponset valley metropolitan sewer, which now discharges into the Dorchester intercepting sewer of the Boston main drainage. The high-level sewer would intercept the Neponset valley sewer above this district, which would remain tributary to the Boston pumping system after the high-level sewer is built.

The sewage from this district could continue to be discharged into the Dorchester intercepting sewer for some years, but the time may come when it would be expedient to divert it to another channel. A small pumping station and force main could then be constructed, and it could be raised to the high-level sewer. This sewage is included in the amount that the high-level sewer is intended to convey; but the cost of constructing this pumping station and force main has not been included in the estimate of costs, as this work may not be undertaken until long after the high-level sewer is in operation.

The total estimate of the cost of the high-level sewer to Moon Island, including the pumping station, force main and other work required for raising the sewage of the Charles River valley, is as follows: —

Estimated cost of constructing the high-level sewer, including engineering and contingencies,	$4,468,798
Estimated cost of rights of way,	176,600
	$4,645,398
Estimated cost of constructing the pumping station and force main for the Charles River valley sewage,	548,740
Total estimated cost by this route,	$5,194,138

The estimated annual expense for maintenance and operation during the decennial period from 1905 to 1915 is $37,500.

THE DISCHARGE OF SEWAGE AT MOON ISLAND.

The route for the high-level sewer described above in detail leads to Moon Island, where the present outfall of the pumping system of the Boston main drainage is situated. The construction of the high-level sewer along this route would concentrate at this point the sewage of the entire district of about 121 square miles, the population of which in 1940 is estimated at 1,550,000 persons. The amount of sewage that would be discharged at Moon Island in the year 1940, under these conditions, is estimated at an average of about 271,000,000 gallons per twenty-four hours, but during long storms it might be increased to about 465,000,000 gallons per twenty-four hours.

The indicated volume of sewage pumped to Moon Island, during the year 1897 varied from about 50,000,000 gallons per day to about 125,000,000 gallons according to the records of the pumping station at Old Harbor Point.

Observations have been conducted under the direction of Mr. H. W. Clark, chemist in charge of the Lawrence Experiment Station of the State Board of Health, to determine the influence which variations in the volume of sewage at Moon Island have upon the extent of the area in the harbor covered by the sewage discharged, and also to determine certain chemical and physical facts relating to the condition of the sewage after it has been discharged and the rapidity with which it is diluted and dissipated into the water of the harbor. The results of these observations are contained in the Appendix.

For these purposes the volume of sewage discharged from the reservoir at Moon Island was caused to vary on different days, and observations were made as to the extent of the sewage tract in the harbor corresponding to each volume discharged. The extent of the sewage tract was found to depend upon the volume of sewage discharged, the direction and force of the tidal currents and the wind.

It was found that the sewage had a tendency to float upon the sea water, the latter having the greater density. The sewage was mingled with the sea water in a small area around the outlet in sufficient quantity to be detected at depths of 4 or 5 feet; but the sewage over the greater part of the area was spread out and diluted as it moved along, and the depth at which it could plainly be detected was reduced to about 2 feet.

The depth then diminished gradually towards the edges of the tract, where the sewage merely formed a film upon the surface of the water.

It follows from the preceding statement that the sewage tract was sensibly divided into three distinct areas: that nearest the outfall was small, and was much discolored; beyond this was an area of much larger extent, in which the discoloration was marked, but of much less density than in the first area; the outer portion of the tract was found to be mainly a thin film of greasy matter from the sewage, which gave to the water an oily or sleek appearance, on which account this portion of the sewage tract has been called the "sleek."

The analyses of samples taken from the sleek and from the discolored area showed that the portion of the sewage tract which contained a considerable amount of organic matter was substantially identical with the area of discoloration, and that the amount of organic matter in the sleek was so minute as not to be a source of offence. The area of discoloration, to which the temporary pollution of the sea water was mainly confined, was usually found to be broken up and dissipated in from two to three hours after the discharge of sewage, depending largely upon the force of the waves.

Such examinations of the shores and bed of the harbor as have been made indicate that no serious pollution of them has resulted from the discharge of sewage, except directly around the outlet and in the small cove near the outlet; but an appreciable pollution can be noted at low tide for some distance around both sides of Moon Island and along the causeway leading to Squantum Head.

The observations on the extent of the sewage tract as compared with the volume of sewage led to the results contained in the following table: —

Volume of Sewage and Extent of Sewage Tract near Moon Island.

DATE.	Volume of Sewage per Twenty-four Hours (Gallons).	Approximate Area of Discoloration (Acres).	Velocity of Wind (Miles per Hour).	Direction of Wind.
September 14, ...	26,000,000	236	5	S. E.
October 13, ...	72,000,000	790	Calm.	-
August 29, ...	92,000,000	760	5	S. E.
July 1, ...	103,000,000	770	8	N. W.

A discharge from the reservoir corresponding to a flow of about 26,000,000 gallons per twenty-four hours made a sewage tract of about 236 acres, and a discharge corresponding to about 92,000,000 gallons made a sewage tract of about 760 acres.

If the sewage from the entire district of 121 square miles should be concentrated at Moon Island, and the volume discharged there daily should be thereby increased to the amounts estimated for the entire district, the extent of the sewage tracts in the harbor would be far greater than at present. As an increase in the volume of sewage from 26,000,000 gallons to 92,000,000 gallons per twenty-four hours caused an enlargement of the sewage tract from 236 acres to 760 acres, it seems reasonable to expect that, if the volume of sewage discharged at Moon Island should become as great as 271,000,000 gallons or 465,000,000 gallons per twenty-four hours, the area of the sewage tracts might be increased to 1,500 or 2,000 acres.

The concentration at Moon Island of all the sewage of the district of 121 square miles would also require successive enlargements of the reservoirs until all the space available on the island had been utilized. An aggregate storage capacity of 130,000,000 or 150,000,000 gallons would then have been secured. If the period of storage between tides should be ten hours, as is usual, the storage of 150,000,000 gallons during each tide would provide for a flow of 360,000,000 gallons per twenty-four hours. The maximum dry-weather flow estimated for the year 1940 is 310,000,000 gallons per twenty-four hours. This amount would be increased if storm water were also to be conveyed to the reservoirs. It is therefore clear that the limit of storage capacity at Moon Island would be likely to be reached about the year 1940 if the sewage from the entire district should be taken there, after which time there would be no possibility of extending the reservoirs at Moon Island to keep pace with the increase in the volume of sewage.

The disposal of the sewage by its discharge into sea water, and its rapid dilution so that it may quickly disappear from sight and smell, can be best obtained by discharging it at a number of points into swift currents, and, if practicable, by continuous flow. In view of this, and of the conditions at Moon Island mentioned above, it would seem advisable to lead the high-level sewer to an outfall at some other point, provided a suitable location at reasonable cost can be found, leaving Moon Island for the future expansion of the low-level pumping system of the Boston main drainage.

The consulting engineer in his report concurs in this opinion, and the observations and conclusions of the chemical expert still further strengthen it.

Outfall for the High-level Sewer at Peddock's Island.

An examination of the chart of Boston harbor shows that there is a channel of considerable depth on the westerly side of Peddock's Island, and an inspection of the locality reveals the fact that strong and well-defined tidal currents of large volume flow by and near to the south-westerly end of the island.

This island has an area of about 150 acres. On it are four hills, which are so grouped as to divide the island into three areas of uplands, connected by two narrow necks. The westerly upland has an area of about 50 acres, and affords an ample and favorable location for reservoirs, since no serious engineering difficulties would be encountered in establishing an outfall at this place.

Peddock's Island is now uninhabited. The settlement nearest to reservoir sites at the westerly end of the island is at Manet Beach on the main land, near Quincy Great Hill. This is a comparatively unimportant summer resort, the population of which varies from less than 100 persons in winter to 1,500 or 2,000 during the warm season. Its nearest point is separated from Peddock's Island by a channel three-quarters of a mile wide.

The average volume of the ebb-tide current that would receive the sewage discharged from a reservoir on Peddock's Island, and the average volumes of the ebb-tide currents which receive the sewage discharged at Moon Island and Deer Island, are given in the following table: —

Average Rates of Flow of Currents of Ebb Tide.

LOCATION OF CURRENT.	Average Flow of Whole Ebb Tide (Cubic Feet per Second).	System from which Sewage is or may be discharged into Current.	Character of Discharge.
Between Rainsford and Long islands, .	72,000	Boston main drainage.	From reservoir.
Between Peddock's and Rainsford islands, .	200,000	High-level sewer, .	From reservoir.
Between Deer and Long islands, . .	269,000	North metropolitan,	Continuous.

It appears from the above table that the volume of the tidal current into which the sewage from reservoirs on Peddock's Island would be discharged is about three times as great as the volume of that into which the sewage from the Moon Island reservoir is usually carried, and that it is nearly equal to the tidal volume at Deer Island into which the sewage from the north metropolitan system has been continuously discharged for about four years.

The tidal currents near Peddock's Island have been studied by means of wooden floats 4 to 11 feet long, weighted at one end so as to float upright with only a few inches exposed above the water.

Thirteen floats were started in mid-channel between the western end of Peddock's Island and Sunken Island Beacon. A study of them led to the following conclusions: —

(*a*) A strong, well-sustained ebb current sweeps through these waters continuing from 1 to 2 miles outside of Boston Light, or from 5 to 6 miles from the starting point, having an average velocity of about 1 mile per hour and a maximum velocity of about 1.5 miles per hour.

(*b*) A float starting from the above-mentioned point at high water will be carried beyond Boston Light, or more than 4 miles from the starting point, in a little less than four hours.

(*c*) The influence of the wind upon this current is very slight, and in no case materially changed the paths of the floats.

(*d*) The floats were generally carried about 2 miles beyond Boston Light, or about 6 miles from the starting point, before the turn of the tide, and did not return to the harbor on the next flood tide.

(*e*) A period of slack water, lasting about an hour, occurs at high water, and the ebb currents are weak until about half an hour after the time of high water.

Other floats, ten in number, were started near the Peddock's Island shore, one hour and two hours after high water, at the probable location for an outfall. The depth at low water was here about 6 feet. A study of these floats led to the following conclusions: —

(*f*) These floats kept closer to Peddock's Island, and had a velocity somewhat less than those from mid-channel.

(*g*) Their average velocity was about 0.9 mile per hour, and they were carried well beyond Boston Light before the next flood tide began.

(*h*) A north or west wind had a considerable influence upon these floats, driving them closer to Peddock's Island.

The results of the float experiments that were made near Moon Island before the construction of the Boston main drainage were as follows: —

> Floats leaving the vicinity of Moon Island with the early ebb would travel seaward with an average velocity of 0.74 mile an hour, passing between Rainsford and Long islands, through Black Rock Channel, and at the turn of tide would reach a position between the Brewsters and George's islands, about 4 miles from the point of starting. Returning with the flood tide, the floats would travel about 2 miles towards the city, and with the succeeding ebb would once more move seaward, not again to enter the harbor.

The above results appear to be the general averages from all tides. Other observations with floats, made by the city of Boston in 1879, from three to seven days before the August spring tides, indicated that floats starting from a point near the outlet one and one-half hours after high water would move with an average velocity of about 0.39 mile, and at the turn of the tide would have reached a point between Rainsford and Long islands about 1.76 miles from the point of starting. As these observations were made during a series of mean tides, the averages derived from them are smaller than would have been the case if the influence of the strong currents of spring tides had been included.

Comparison between the Conditions of Discharge at Peddock's Island and Those at Moon Island.

The average velocities of the ebb currents near Peddock's Island vary from 0.9 to 1.0 mile per hour. Near Moon Island they vary from 0.39 to 0.74 mile per hour.

Floats leaving Peddock's Island soon after high water were generally carried about 2 miles beyond Boston Light, and did not return to the harbor on the next flood tide. Floats leaving Moon Island with the early ebb would reach the vicinity of Boston Light at low water, and would return about 2 miles with the next flood tide, to be finally carried to sea with the succeeding ebb.

The tidal volume into which the sewage from reservoirs on Peddock's Island would be discharged is about three times as great as that into which the sewage from Moon Island is now discharged.

Route of the High-level Sewer to Peddock's Island.

Peddock's Island is separated from the main land at Hough's Neck in Quincy by a channel about three-quarters of a mile wide. The distance to Nut Island is only about half a mile, and this island is connected with Hough's Neck by a shoal which is bare at low water.

A site for a reservoir at Peddock's Island can be obtained by grading the comparatively level ground forming the southerly point. The discharge sewers from the reservoir would be of sufficient size to discharge the contents of the reservoir when full in about one hour, and would extend in embankment about 500 feet from the present shore to a point where the depth of water is about 6 feet at low tide.

The shore of the island is here concave for a long distance. The estimate includes the cost of placing the earth removed in grading so as to modify the shore line near the outlet in such a way as to check any tendency to deposit sewage matter in this vicinity. If found desirable in the future, a channel might be cut through the narrow neck near Prince's Head, and be arranged with sluice gates which could be opened at the proper stage of the tide, and induce a current to remove any slight traces of sewage matter which might occasionally lodge near the island.

A reservoir having a capacity of 40,000,000 gallons, filled in ten hours during each tide, would provide for a daily flow of 96,000,000 gallons. The maximum daily dry-weather flow would attain this amount about the year 1920. After that time additional capacity could be obtained by constructing a second reservoir adjoining the one first built.

The bottom of the reservoir would be about 7 feet above low tide, or 107 feet above the datum of levels used for the metropolitan sewers. The reservoir would be filled to a depth of about 13 feet, or to about 120 feet above datum. These levels will cause the discharge from the reservoir to be rapid, and at the same time keep the high-level sewer at a comparatively low elevation.

Sewage would be conveyed across the channel between Nut and Peddock's islands in an inverted siphon of cast-iron pipes, 60 inches in diameter. They would be laid in a dredged trench, following approximately the shape of the bottom of the channel, and would be covered over, so as to be protected against accidents. The siphon would consist at first of two lines of pipes. The number would be increased in the future, and the structures on the shores with which the siphon connects would be built so as to be ready for these additions. Estimates have been made of the cost of a masonry siphon at this point; but the favorable prices of cast-iron pipes, their reliability, strength and convenience in handling, have led to their adoption for the purposes of this study.

On Nut Island the sewage would be sufficiently screened to intercept paper, rags and other floating matters that might prove unsightly in the harbor; and a sand-catcher would be built, which would intercept sand and heavier matters which might occasion trouble in the siphons.

The high-level sewer proper would begin at the sand-catcher on Nut Island, 11 feet 4 inches by 12 feet in size internally, with its invert at elevation 110 feet above datum. This size would continue through Quincy to a point near Hancock Street, the sewer rising at the rate of 1 foot in 3,500 feet, and attaining an elevation of 116.05. It would be covered by an embankment between Nut Island and the main land, and would be built by tunnel through Quincy Great Hill. Between this point and Hancock Street the sewer would be partly in embankment and partly in excavation.

At Hancock Street the size is reduced to 11 feet 1 inch by 11 feet 9 inches. These dimensions would continue to a point near Beale Street, the sewer attaining an elevation of 118.48. This portion of the sewer would be largely in excavation. There would be a short tunnel near Hancock Street.

From near Beale Street the size is reduced to 10 feet 10 inches by 11 feet 6 inches. This would continue to Adams Street in Milton, the sewer attaining an elevation of 119.28 at that place. The sewer from Milton Street to Adams Street would be largely in tunnel.

The route of the high-level sewer beyond Adams Street in Milton passes through the valleys of Unkety and Pine Tree brooks, occupying the location described for the high-level sewer by the second route to Moon Island, on pages 57 and 58. The sizes, elevations and gradients are the same as there described. At the junction of Catalpa and Castleton streets in West Roxbury the sewage of the Charles River valley sewer would be received from the sewers, pumping plant and force main already described in connection with the Moon Island route.

This route of the high-level sewer with the outlet at Peddock's Island is shown on Plate No. 4 by a heavy red line. Its extension to Newton is shown by the dotted red line. The metropolitan sewers in the valleys of the Charles and Neponset rivers are shown by the broken red lines. The intercepting sewers, tunnel and outfall sewers of the Boston main drainage are shown by the broken brown lines. The districts from which sewage can be received by gravity into the high-level sewer are shown by the green tint. Those from which the sewage must be pumped to the high-level sewer are shown by the blue tint. Those remaining tributary to the pumping station of the Boston main drainage are shown by the buff tint. Many details shown on this plate are the same as those shown on Plate No. 3, described on page 49.

Estimate of Cost.

The following is an estimate of the cost of constructing the high-level sewer by this route from Peddock's Island to the junction of Castleton and Catalpa streets in West Roxbury: —

Estimated Cost of High-level Sewer from Peddock's Island to Junction of Castleton and Catalpa Streets, West Roxbury.

SECTION.	Diameter of Sewer.	Length of Section (Feet).	Cost.	Remarks.
Construction on Peddock's Island, outlet and discharge sewers, reservoir (40,000,000 gallons capacity) and outfall sewer.	10' 10"×12', 11' 4"×12',	2,580	$806,732	Roadways, improving shore-line.
Siphon between Peddock's Island and Nut Island, . .	60", ...	2,940	117,600	Two lines of 60-inch cast-iron pipe and head house.
Construction on Nut Island, screen house, sand-catcher and overflow.	- -	280	66,395	Open earth cut.
Main sewer in embankment on Nut Island and Nut Island bar.	11' 4"×12', ...	1,100	53,400	Earth excavation and embankment.
In private land (marsh and upland), Sea and Greenleaf streets, to Hancock Street, Quincy.	11' 4"×12', ...	20,080	782,325	Earth tunnel for 850 linear feet, open earth cut for 10,180 linear feet, embankment for 650 linear feet, earth cut and embankment for 8,400 linear feet.
In private land and Adams Street to the boundary line between Quincy and Milton.	11' 1"×11' 9", . .	8,500	479,148	Rock tunnel for 2,100 linear feet, earth tunnel for 1,930 linear feet, open earth cut for 2,820 linear feet, earth and rock cut for 1,650 linear feet.
In Adams Street to a point about 600 feet west of East Milton station.	10' 10"×11' 6", . .	2,799	171,568	Rock tunnel for 1,000 linear feet, earth tunnel for 1,470 linear feet, earth and rock cut for 329 linear feet.
In private land to a point in Randolph Avenue, about 1,100 feet North of Centre Street.	10' 8"×11' 4", . .	6,907	207,210	Open earth cut.
In private land, Canton Avenue and Brook Road, in Milton, and private land and Mattakeeset Street in Hyde Park to East River Street.	10' 7"×11' 2", . .	9,917	389,696	Neponset River crossing, rock tunnel for 1,100 linear feet open earth cut for 7,921 linear feet, earth and rock cut for 700 linear feet, Neponset River crossing for 196 linear feet.
In private land Ralston Road and Ruskin Road, to the boundary line between Hyde Park and West Roxbury.	9' 3"×9' 9", ...	7,163	337,665	Stony Brook crossing, rock tunnel for 4,500 linear feet, open earth cut for 1,690 linear feet, earth and rock for 897 linear feet, Stony Brook crossing for 76 linear feet.
In private land, Hammatt Road, Hadwin Way, Hyde Park Avenue, Larch Place, Harrison Street, Arborway and South Street in West Roxbury to Centre Street.	8' 10"×9' 4", . .	13,478	386,656	Two brook crossings under sewer, earth tunnel for 1,824 linear feet, open earth cut for 5,884 linear feet, earth and rock cut for 800 linear feet, earth cut and embankment for 3,920 linear feet, earth cut and pile foundation for 1,050 linear feet.
In private land, Centre Street and Catalpa Street, to Castleton Street.	8' 3"×8' 9", ...	5,352	251,287	Earth tunnel for 1,156 linear feet, rock tunnel for 4,196 linear feet.
Total, ...			$4,049,682	
Engineering and contingencies, 15 per cent., ...			607,452	
Total cost of construction, ...			$4,657,134	
Rights of way, ...			219,100	
Total cost of main line, ...			$4,876,234	

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Estimated Cost of High-level Sewer from Peddock's Island to Junction of Castleton and Catalpa Streets, West Roxbury.

SECTION.	Diameter of Sewer.	Length of Section	Cost

Cost of Pumping System for Charles River Valley.

The pumping station, forcing main, sewers and other work required to raise the sewage of the Charles River valley to the high-level sewer are the same as those already described in connection with the route to Moon Island. The detailed estimate of the cost of this pumping system is given in the table on pages 61 and 62, the total being $548,740, including engineering and contingencies.

The total estimate of the cost of the high-level sewer to Peddock's Island, including reservoirs, outfall and all accessory works, and including the force main and other work required for raising the sewage of the Charles River valley is as follows: —

Estimated cost of constructing the high-level sewer, including engineering and contingencies, ...	$4,657,134
Rights of way, ...	219,100
Total cost of main line, ...	$4,876,234
Estimated cost of constructing the pumping station and force main for the Charles River valley sewage, ...	548,740
Total estimated cost by this route, ...	$5,424,974

The estimated annual expense for maintenance and operation during the decennial period from 1905 to 1915 is $37,500.

The cost of constructing the high-level sewer by the Peddock's Island route is estimated at $230,836 more than by the Moon Island route. This is about 4 per cent. of the total estimated cost, or less than the allowance for contingencies in the estimates, so that the cost of the high-level sewer by either route is substantially the same. Important advantages would be gained by placing the outfall at Peddock's Island. The most important is that the works at Peddock's Island may be continually expanded and adapted to the growth of the system, while at Moon Island the limit of expansion might be reached about 1940, and then the continuance of an intermittent discharge at that place would become impracticable. Better results are to be expected from the discharge of sewage from an outfall at Peddock's Island than from one at Moon Island, on account of the stronger velocities, the quicker passage to the sea and the larger tidal volume existing near the former.

Outlet recommended for Continuous Discharge near Nut Island.

The investigations relating to an outlet at Peddock's Island for the high-level sewer, with a reservoir and intermittent discharge, have disclosed the fact that the volume of the ebb-tide current near Peddock's Island is nearly as great as that near Deer Island, where a continuous discharge of sewage from the north metropolitan system was recommended in 1889 by the State Board of Health, after elaborate investigations, and has been in successful operation for about four years.

Examinations of the chemical and physical conditions resulting from this continuous discharge at Deer Island have been made during the summer and fall of 1898, to determine whether it might be expedient to discharge the sewage from the high-level sewer continuously near the westerly end of Peddock's Island. The results of these examinations and analyses are given in detail in the report of the chemical expert, in the Appendix. The conclusions from these investigations at Deer Island may be briefly stated as follows: —

The volume of sewage discharged on the days when the observations were in progress varied from about 40,000,000 to 50,000,000 gallons per twenty-four hours.

The distribution of the sewage in the sea water was found to be very similar to that at Moon Island. The sewage tract was divided into three distinct areas. That nearest the outlet was strongly discolored; beyond this was a second area of larger extent, in which the discoloration was less strongly marked; and outside of all was an area in which only the sleek was found. The discoloration almost entirely disappears in one and one-quarter hours after leaving the outlet, during which time the sewage is carried about one and one-eighth miles, and beyond this distance on calm days the sleek only can be found. The area covered by the discolored field during the ebb tide does not usually exceed 350 acres. On calm days the area, including the sleek, may be about 450 to 500 acres.

Samples collected near the surface in the part most discolored were found to contain about 30 per cent. of sewage. This percentage diminishes rapidly as the distance from the outlet increases. The amount of sewage in samples collected at 900 feet from the outlet was only 3 per cent., and samples collected at the visible limit of the sewage field were found to consist of nearly normal sea water. Samples taken at the surface, at intervals of fifteen minutes, following the band of sewage during the ebb tide, show a regular decrease in the percentage of sewage present, as follows: —

Percentage of Sewage found in Surface Samples.

15 minutes after leaving outlet,	20
30 minutes after leaving outlet,	15
45 minutes after leaving outlet,	5
60 minutes after leaving outlet,	4

The percentage is less below the surface. Traces of sewage can be detected at a depth of 5 feet near the outlet. This depth decreases rapidly towards the edges of the area, as is the case at Moon Island. Samples taken for analysis from the area of sleek show practically no organic matter, as the sleek itself is simply an exceedingly thin film of grease upon the surface of the water.

During the flood tide the discoloration almost entirely disappears in one and one-half hours after leaving the outlet, during which time the sewage is carried about 1 mile. The discolored area was found to be about 300 acres. On calm days the area, including the sleek, may be about 500 acres.

The sewage discharged at Deer Island is in a much fresher condition, and consequently has less odor than that at Moon Island, which is stored in the reservoir several hours. The depth of water over the Deer Island outlet at high tide is about 9 feet. The outlet is nearly bare at low tide. The duration of slack water at high tide is about three-quarters of an hour at this outlet.

A comparison of the tidal conditions shows that the average volume and velocity of the ebb current north of Peddock's Island are very nearly the same as those of the ebb current near Deer Island. There are no habitations on Peddock's Island, and the chart of Boston harbor shows that there are no flats of any considerable extent near it.

It seems reasonable, therefore, to expect that, if the sewage were to be discharged continuously into the ebb current north-west of Peddock's Island, the area of discoloration and the distance to which it would be carried under average conditions would be substantially the same as at Deer Island; and that, under average conditions, it would have very nearly disappeared when the discoloration had been carried about 1 mile, or before it would have reached the easterly end of Peddock's Island.

It may be concluded, therefore, that sewage may be discharged continuously into the ebb currents north-west of Peddock's Island with results about as good as those attained at Deer Island.

The question as to the probable effect of a continuous discharge of sewage during the flood tide from the outlets at points near Peddock's Island, shown on Plate No. 5, has received special attention. The flood current divides near Sunken Island Beacon, one part going towards Quincy Bay with small velocity, the other running into Hingham Bay with good velocity. It has been found that there is a region west of Peddock's Island in the deepest part of the channel where the flood currents are strong and set towards Hingham Bay exclusively. The outlets shown on Plate No. 5 are within this region.

Observations made by means of thirty-two floats, started from this locality during the flood tide, lead to the following conclusions: —

1. None of the floats went towards Hough's Neck nor Manet Beach.
2. Such floats as were carried to any shores required three hours or more in the passage, which is double the time required at Deer Island to dissipate the discoloration produced by the sewage.
3. The floats were mostly carried into the west central part of Hingham Bay.
4. The floats running into Hingham Bay during the flood tide were generally carried out of it on the succeeding ebb, either through Nut Island Channel or through Hull Gut.

A comparison of the tidal conditions shows that the average velocity of the flood current through Nut Island Channel is about the same as that of the flood current near Deer Island. Observation shows that the discolored portion of the sewage field produced by the continuous flow of sewage into the flood-tide current near Deer Island has very nearly disappeared after it has been carried about one mile, which requires about one and one-half hours. It may therefore be concluded that the discoloration produced by a discharge of sewage into the channel west of Peddock's Island might be carried by the flood currents following the thread of the channel, which is about midway between Quincy Great Hill and Peddock's Island, about to a line from the Great Hill to Prince's Head. From the action of the floats it may be concluded that a sewage field entering Hingham Bay with the flood tide would not approach the small summer settlement at Manet Beach, and would require so long a time to reach any shores that the sewage would be diffused and rendered inoffensive before the shores were reached.

The average volume of the tidal current which passes Nut Island during the ebb tide was found to be about 77,000 cubic feet per second. The average volume would be somewhat less during the flood tide, owing to the holding back of the river waters. The average flood volume appears, therefore, to be about the same as the average volume of the ebb current off Rainsford Island, — 72,000 cubic feet per second, — into which the sewage discharged at Moon Island is usually carried.

The tidal currents near Nut Island seem, therefore, to present conditions favorable for the continuous discharge of sewage for a long series of years, if not perpetually, at the outlets shown on Plate No. 5. Should it be found, after some years, that better results would be attained if the sewage were stored in a reservoir during a portion of the flood tide, it would then be practicable to construct such a reservoir on Peddock's Island, with discharge channels leading northerly. This reservoir would be connected with the screen-chamber and gate-house on Nut Island by independent lines of iron pipes, such as were described for the Peddock's Island outlet. The discharge would then be from a reservoir, supplemented by a continuous flow from other outlets. It is not thought that this modification of the system would ever be required.

Outfall Works for Continuous Discharge near Nut Island.

The outfall works for a continuous discharge of sewage near Nut Island would consist at first of two lines of extra heavy cast-iron pipes, 60 inches in diameter, laid in a dredged trench substantially as shown on Plate No. 5, and covered for protection against injury. The connecting chambers at the shores would be designed so that additional lines of pipes could be laid in the future if needed.

The outlet would be near the bottom of the channel, about 3,000 feet northerly from Nut Island. Its depth would be about 26 feet below low water and about 35 feet below high water. These depths compare favorably with those of the outlet at Deer Island, which is nearly bare at low water and is covered only about 9 feet at high water. The greater depth of the Nut Island outlet would induce a more rapid dilution of the sewage.

The pipes would leave Nut Island from a screen-house provided with gates and screens for intercepting floating matters. There would also be a sand-catcher on Nut Island, of sufficient dimensions to intercept heavier matters that might cause trouble in the pipes.

The high-level sewer would follow the route already described for the Peddock's Island outlet and shown on Plate No. 4. The general position of the Nut Island outlet is shown on Plate No. 5.

Estimate of Cost.

The following is an estimate of the cost of construction of the high-level sewer from Nut Island to the junction of Castleton and Catalpa streets in West Roxbury: —

Engineering and contingencies, 10 per cent.,	
Total cost of construction,	$3,761,708
Rights of way,	169,100
Total cost of main line,	$3,930,808

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Estimated Cost of High-level Sewer from Nut Island to Junction of Castleton and Catalpa Streets, West Roxbury.

SECTION.	Diameter of Sewer.	Length of Section (Feet).	Cost.	Remarks.
Outlet sewer, ...	60" pipes, .	5,660	114,200	Two lines, 60-inch cast-iron pipes.
Construction on Nut Island, screen house, sand-catcher, overflow.	-	280	97,895	Open earth cut.
Main sewer in embankment on Nut Island and Nut Island bar.	11' 4"×12', .	1,100	53,400	Earth excavation and embankment.
In private land (marsh and upland), Sea and Greenleaf streets, to Hancock Street, Quincy.	11' 4"×12', .	20,080	782,325	Earth tunnel for 850 linear feet, open earth cut for 10,180 linear feet, embankment for 650 linear feet, earth cut and embankment for 8,400 linear feet.
In private land and Adams Street to the boundary line between Quincy and Milton.	11' 1'×11' 9", .	8,500	479,148	Rock tunnel for 2,100 linear feet, earth tunnel for 1,930 linear feet, open earth cut for 2,820 linear feet, earth and rock cut for 1,650 linear feet.
In Adams Street to a point about 600 feet west of East Milton station.	10' 10"×11' 6",	2,799	171,568	Rock tunnel for 1,000 linear feet, earth tunnel for 1,470 linear feet, earth and rock cut for 329 linear feet.
In private land to a point in Randolph Avenue, about 1,100 feet north of Centre Street.	10' 8"×11' 4", .	6,907	207,210	Open earth cut.
In private land, Canton Avenue and Brook Road in Milton, and private land and Mattakeeset Street in Hyde Park to East River Street.	10' 7"×11' 2", .	9,917	389,696	Neponset River crossing, rock tunnel for 1,100 linear feet, open earth cut for 7,921 linear feet, earth and rock cut for 700 linear feet, Neponset River crossing, 196 linear feet.
In private land Ralston Road and Ruskin Road to the boundary line between Hyde Park and West Roxbury.	9' 3"×9' 9", .	7,163	337,665	Stony Brook crossing, rock tunnel for 4,500 linear feet, open earth cut for 1,690 linear feet, earth and rock cut for 897 linear feet, Stony Brook crossing for 76 linear feet.
In private land, Hammatt Road, Hadwin Way, Hyde Park Avenue, Larch Place, Harrison Street, Arborway and South Street in West Roxbury to Centre Street.	8' 10"×9' 4", .	13,478	386,656	Two brook crossings under sewer, earth tunnel for 1,824 linear feet, open earth cut for 5,884 linear feet, earth and rock cut for 800 linear feet, earth cut and embankment for 3,920 linear feet, earth cut and pile foundation for 1,050 linear feet.
In private land, Centre Street and Catalpa Street, to Castleton Street.	8' 3"×8' 9" .	5,352	251,287	Earth tunnel for 1,156 linear feet, rock tunnel for 4,196 linear feet.
Total, ...			$3,271,050	
Engineering and contingencies, 15 per cent., ...			490,658	
Total cost of construction, ...			$3,761,708	
Rights of way, ...			169,100	
Total cost of main line, ...			$3,930,808	

The total estimate of the cost of the high-level sewer to Nut Island, including the outfall and all accessory works, and including the force main and other work required for raising the sewage of the Charles River valley, is as follows: —

Estimated cost of constructing the high-level sewer, including engineering and contingencies,	$3,761,708
Rights of way,	169,100
Total cost of main line,	$3,930,808
Estimated cost of constructing the pumping station and force main for the Charles River valley sewage,	548,740
Total estimated cost,	$4,479,548

The estimated annual expense for maintenance and operation during the decennial period from 1905 to 1915 is $29,000.

The estimated cost of the high-level sewer with continuous discharge from outlets at points off Nut Island is about $714,000 less than the cost if the outlet were at Moon Island with a reservoir, and about $945,000 less than the cost if the outlet were at Peddock's Island with a reservoir. But these figures do not indicate the entire saving that would result from placing the outlet off Nut Island. The annual cost of operating and maintaining a reservoir is estimated at about $10,000, which, at 3 per cent., would be the interest of $333,333. This capital would be saved by omitting the reservoir, and the gross capitalized saving effected by placing the outlet off Nut Island is therefore about $1,278,000, as compared with an outlet at Peddock's Island.

The continuous discharge of sewage at points off Nut Island is more desirable than an intermittent discharge from a reservoir, either at Moon Island or at Peddock's Island, and is recommended for the following reasons: —

1. The saving in first cost and capitalized cost of maintenance is $1,278,000, when comparison is made with the Peddock's Island project.

2. The discharge of sewage is in a continuous stream of moderate dimensions and in a fresh condition, instead of intermittently, in large volume and in a stale condition from a reservoir.

3. The discharge of sewage is made into tidal currents of large volume and velocity, at a point where the ebb current has

sufficient strength to carry the sewage beyond a location where the discoloration would disappear, and where the flood current would not leave traces of sewage near the shores.

4. The usual conditions of flow would generally be continued, and the lower lengths of the outfall sewer would not be flooded, as they would be if the sewer were to discharge into a reservoir nearly full. The formation of gases and deposits in the sewer would consequently be avoided. There would be little or no setting back of the sewage during average conditions of high tide.

The arrangement now made for disposing of the sewage of the city of Quincy requires that it shall all be pumped to the outfall sewer of the Boston main drainage, the lift being about 30 feet when the reservoir is full.

When the sewage of Quincy is conveyed to the high-level sewer, a part of it may enter by gravity, without pumping, and the remainder must be pumped about 18 feet. It could be raised by the pumping plant already installed to pump sewage to the Boston outfall.

All the large sewage pumping plants connected with the metropolitan sewerage systems are the property of the Commonwealth, and are operated as component parts of those systems. It seems expedient, therefore, that the pumping plant of the city of Quincy should also become the property of the Commonwealth. The cost of acquiring this property is estimated at about $100,000, which sum should be added to the foregoing estimates for the high-level sewer, making the entire cost of the Nut Island project $4,579,548.

Review of the Annual Charges for Maintenance and Operation in the South Metropolitan Sewerage District.

The sewage from the metropolitan districts in the Charles and Neponset valleys is now discharged into the intercepting sewers of the Boston main drainage, and is conveyed to the outfall at Moon Island. The amounts asked by the city of Boston for disposing of the sewage from these metropolitan districts in this manner are given for a number of years in the annual report of the street department for 1896, page 362. The charge there estimated for the year 1910 is $102,000.

This amount was based upon a valuation of about $5,000,000 for those portions of the Boston main drainage works used by the Charles and Neponset metropolitan sewerage systems; but their cost is to be increased about $500,000 for new reservoirs and other works at Moon Island now in course of construction, and it is probable that, when the new pumping plant now being designed for the pumping station at Old Harbor Point is in operation, the total cost of said portions of the main drainage works may approximate $6,000,000. This increase in valuation might cause an increase of about $10,000 in the rental, making the charge for the year 1910 about $112,000.

The year 1910 is the middle year of the decennial period extending from 1905 to 1915. This is probably the first decennial period that can be used for a comparison of charges, as it may be some years before the proposed high-level system can be constructed and put in operation.

Annual Cost of Existing Metropolitan Sewers in the Charles and Neponset Valleys.

The total expenses for a given year would comprise any rental paid to the city of Boston, the payments for interest and sinking fund charges, and the cost of maintenance and operation. The annual interest and sinking fund charges against the Charles and Neponset valleys for the existing metropolitan sewers have been estimated for the years from 1905 to 1914 inclusive, from information obtained from the office of the State Treasurer. The annual cost of maintenance and operation has been estimated from the records of the Metropolitan Sewerage Commission.

These various charges, estimated for the year 1910, are as follows: —

Probable rental to be paid to the city of Boston, ...			$112,000
Interest and sinking fund charges for the metropolitan sewerage loans: —			
Charles River, ...	$30,720		
Neponset River, ...	33,410		
		$64,130	
Maintenance of metropolitan sewers, ...		5,000	
			69,130
Total for the year 1910, ...			$181,130

This estimate rests upon the assumption that the capacity of the existing Boston main drainage works would in other respects be equal to the handling of the sewage until the year 1910; an assumption which is inexact. If the city of Boston should in the mean time build a high-level sewer for its own relief, as is recommended by its officials, the rental might be largely increased.

Annual Cost of the South Metropolitan System.

The district which is to be tributary to the high-level system is to be known as the south metropolitan system. It includes, among others, the districts composing the Charles and Neponset metropolitan sewerage systems.

A forecast of valuation similar to that used by the apportionment commissions has been made for the year 1900, based upon the valuations given in chapter 232 of the Acts of 1898, which is intended to cover the triennial period 1898, 1899, 1900. The valuations in the various fractional districts in Boston which are included in the south metropolitan system are based upon the valuations given in the annual report of the assessing department, which gives the valuation in each ward. These ward valuations were increased in proportion to the totals, so as to make the valuations agree with the estimated valuations of Boston in 1900, as given in said chapter.

A forecast of population has also been made for the year 1900, as it is important, for purposes of comparison, that the estimated valuations and populations should be those for the same year.

There appears to be no reliable way to estimate valuations ten or twelve years in advance, and it is thought that these ratios for the year 1900 may be a reasonable forecast for the year 1910. They have, therefore, been so used in this discussion.

The estimated expenses for the year 1910 are used to represent approximately the average annual expenses during the decennial period from 1905 to 1915. They are as follows: —

Interest and Sinking Fund Charges in 1910.

Charles River valley,	$30,720	
Neponset valley,	33,410	
Proposed high-level project @ 3½ per cent. on estimated cost to Nut Island outlet ($4,579,548),	160,284	
		$224,414

Maintenance Charges in 1910.

Pumping station, Charles River line, ...	$12,000	
Maintenance of Charles and Neponset lines, . . .	3,000	
Disposal of sewage in Neponset intercepter below Hyde Park, rental to Boston, ...	3,000	
Maintenance of main line high-level sewer, . . .	6,000	
Quincy pumping station, ...	5,000	
		$29,000
Total in 1910, ...		$253,414

It seems probable that, for purposes of assessments, the entire south metropolitan system will be treated as a whole by future apportionment commissions, and it is assumed that the charges for interest, sinking fund and maintenance, both for the existing Charles and Neponset metropolitan systems and for the other portions of the south metropolitan system, will be united, and that these assessments will be apportioned on the same bases as are the present metropolitan sewerage loans, — namely, the interest and sinking fund charges on the basis of valuation, and the maintenance charges on the basis of population.

The valuation of the present Charles and Neponset metropolitan districts is about 71.73 per cent. of the valuation of the south metropolitan district. They may, therefore, be called upon to pay that percentage of the interest and sinking fund charges.

The population of these districts is about 68.14 per cent. of the population of the south metropolitan district, and they may be called upon to pay that percentage of the maintenance charges.

The total expenses that these districts might be called upon to pay in 1910 may therefore be as follows: —

For interest and sinking fund, 71.73 per cent. of $224,400, . .	$160,962
For maintenance, 68.14 per cent. of $29,000, ...	19,760
Total in 1910, ...	$180,722

It has been shown that the probable charges to those districts in 1910 would be about $181,130 if the capacity of the existing Boston main drainage works were sufficient to allow the present rental system to be continued until that time. Thus the south metropolitan system, if constructed by the Commonwealth, would cause the annual expense falling upon the present Charles and Neponset metropolitan systems as a whole to be about the same, during this decennial period, that it would be if the present rental system could be continued; but it has been shown in the earlier part of this report that the capacity of the Boston main drainage will soon prove to be inadequate, and that relief such as would be afforded by this high-level project must soon be provided. The construction of the high-level sewer by the Commonwealth would result in this great advantage, — that the district would then own the system of works, instead of continuing the payment of a large rental perpetually.

Although the above comparison shows that the annual expense to the Charles and Neponset valleys as a whole would be about the same in each of the assumed cases, the amounts to be paid into sinking funds are different, about $20,000 more being called for in the case of the south metropolitan system. This amount would be a relative saving, as the money would be paid for a permanent investment instead of for a rental.

The total expense to the south metropolitan district in 1910, estimated at about $253,400, would probably be divided somewhat as follows: —

Boston, including areas in the existing metropolitan districts,	$106,190
Charles and Neponset valleys, excluding Boston,	133,060
Quincy,	14,150
Total,	$253,400

CONCLUSIONS.

This examination of the questions relating to the high-level sewer has led to the following conclusions: —

The area of the territory the sewerage systems of which, so far as they are developed, are connected with the Boston main drainage works, is more than double the area originally intended to be tributary to them.

The volume of sewage reaching the pumping station of the Boston main drainage is already so great as to exceed the continuous working capacity of the works during heavy and long-continued storms. This is shown by —

1. The abnormal depth of flow in the Charles River metropolitan sewer for considerable periods of time, resulting in the closing of the regulators and the overflow of sewage into Charles River through storm outlets during such periods.

2. The estimates of the quantity of sewage made during this examination, which shows that the capacity of the works is reached during storms.

3. The fact that those in charge of the sewer division are already aware of the necessity of providing an early relief for the pumping system, and recommend the construction of a high-level sewer for that purpose. (See report of street department, 1896, pages 329 and 363.)

The capacity of the high-level sewer should be adequate to meet the needs of the district until the year 1940, at which time there would be a tributary population on both high and low areas, estimated at about 1,550,000 persons.

It seems unwise to concentrate the sewage from so large a population and to discharge it at one place, as Moon Island. It seems better to discharge it at more than one outlet, and to lead the high-level sewer to an outlet into the strong tidal currents near Peddock's Island, leaving Moon Island for the future expansion of the low-level pumping system.

The cost of the high-level sewer, with reservoir and outlet at Moon Island, is estimated at $5,194,000; and with reservoirs and outlet at Peddock's Island, at $5,424,974. The annual cost of maintenance is estimated at $37,500, in either case. There is little choice between these two locations as regards cost; but, as Peddock's Island presents an almost unlimited opportunity for future expansion, and is situated near stronger tidal currents which can convey to sea a larger volume of sewage, it seems preferable, if the discharge is to be made from a reservoir.

It is found to be practicable to convey the sewage to the strong tidal currents near Peddock's Island by means of submerged pipes leading from Nut Island, and to discharge it by continuous flow, as is done at Deer Island. This method of disposal is recommended for the following reasons: —

1. The strength and volume of these currents are about the same as those of the currents near Deer Island, where a continuous discharge of sewage has been in operation for several years.

2. The diffusion of the sewage into the waters of the harbor would be more rapid if it were discharged continuously in a stream of moderate size, instead of being stored for nearly half a day and then discharged in bulk in a comparatively short time.

3. The sewage would be discharged into tidal currents of large volume and high velocity, and the discoloration of the harbor water would disappear before any shores were reached.

4. The usual conditions of flow would generally be continued, and the lower lengths of the outfall sewer would not be flooded, as they would be if the sewer were to discharge into a reservoir when nearly full. The formation of deposits and gases within the sewer would consequently be avoided. There would be little or no setting back of the sewage during average conditions of high tide.

5. The saving in first cost and in the capitalized cost of maintenance which would result from discharging the sewage continuously from Nut Island instead of from a reservoir on Peddock's Island is estimated at about $1,278,000. As the reservoir and outfall works are enlarged from time to time, to provide for the increasing quantity of sewage, this capitalized difference of cost would also increase.

6. Estimates made for the year 1910 indicate that the relief obtained by the high-level sewer would cause no greater annual expense to the existing Charles and Neponset metropolitan districts as a whole than is now incurred under the present rental scheme, and that it would cause about $20,000 more to be paid into sinking funds annually during the period from 1905 to 1915 than would be the case under the present rental. This would be a relative saving, as it would be paid for a permanent investment for a few years, instead of for a rental perpetually.

The following engineers and their assistants have been engaged on the investigations and studies for this report: —

Charles H. Swan, assistant engineer, in charge of the special hydraulic studies, and the preparation of the text of this report.

Francis L. Sellew, assistant engineer, in charge of the preparation of maps, plans and estimates, and studies of the engineering details.

Frederick D. Smith, assistant engineer, in charge of the hydrographic surveys and studies.

C. Barton Pratt, assistant engineer, in charge of topographical and geological surveys.

Thomas Bloomfield, in charge of the clerical and stenographic work.

Respectfully submitted,

WILLIAM M. BROWN, Jr.,
Chief Engineer.

APPENDIX.

Report on the Degree and Area of Pollution of the Harbor Water caused by the Present Discharge of Sewage at Moon Island and Deer Island.

By H. W. Clark, Chemist to the State Board of Health.

Lawrence, Mass., Dec. 9, 1898.

William M. Brown, Jr., C.E., *Chief Engineer and Superintendent, Metropolitan Sewerage Commissioners.*

Sir: — I make the following report on the examination into the degree of pollution of the harbor caused by the volume of sewage discharged at the Moon Island and Deer Island sewer outlets.

This examination has been made with the following objects in view: first, to make a comparison of the volume and composition of the sewage discharged at Moon Island and that discharged at Deer Island; second, to ascertain the effect upon the harbor, in the immediate vicinity of each outlet, during discharges of sewage, as to the area covered by sewage, the depth of the layer of sewage, and the distance from the outlets reached by the sewage before it becomes so mixed with sea water that it fails to be recognized either by the appearance of the water or by chemical analysis; third, to determine whether there is any permanent pollution of the water and shores of Quincy Bay caused by the discharge of sewage at Moon Island; fourth, to obtain, if practicable, sufficient data to indicate the effect of discharging from Moon Island, at each tide, volumes of sewage two or three times as great as those now discharged there.

Each sewer outlet has been visited frequently, to observe the degree of pollution of the harbor in its vicinity; series of samples have been collected from different areas in the harbor, in order to study the diffusion of the sewage; the movement of the sewage through the water from each outlet has been observed; and observations of the currents have been made with floats.

The sewage is discharged from the Deer Island outlet in a continuous stream. This outlet is about 9 feet below the surface of the water at ordinary high tide. It is consequently nearly at the level of low tide. On the other hand, the discharge of sewage at Moon Island was intended to be wholly from a reservoir, into which the sewage is pumped and from which it is discharged about one hour after each high tide. The reservoir holds about 22,000,000 gallons, but this capacity is now insufficient, and the reservoir is being enlarged to nearly double its present capacity. The discharge from the reservoir is now supplemented by a continuous discharge of sewage from the outlet, which frequently equals or exceeds the volume stored in and discharged from the reservoirs.

The characteristic outlines of the sewage areas produced by the discharge of sewage at Moon Island and Deer Island are given on the annexed map.

QUALITY OF SEWAGE DISCHARGED FROM EACH OUTLET.

Samples of sewage were collected daily during the month of September at the Deer Island pumping station, at the screen chamber of the Boston main drainage works at Old Harbor Point, and at the Moon Island reservoir. The samples collected at Deer Island and at Old Harbor Point were "twenty-four hour samples," that is, one twenty-fourth of a gallon of sewage was collected each hour during the twenty-four, and turned into a gallon bottle. The gallon of sewage collected in this way was the sample analyzed. The samples collected at the Moon Island reservoir were taken during the discharge, which lasts but three-quarters of an hour, the method being simply to fill the bottle at once during the discharge.

The following table shows the average composition of the sewage during September, 1898: —

[Parts per 100,000.]

LOCALITY.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Deer Island pumping station, . . .	2.15	.69	330
Old Harbor Point, ...	2.26	.69	155
Moon Island reservoir, . . .	1.72	.48	236

These averages show that the amount of organic matter in the samples collected at Deer Island and at Old Harbor Point was about the same, volume for volume. The greater amount of chlorine found in the Deer Island sewage is due to the fact that large amounts of salt water used daily by various industrial works are allowed to flow into this sewer.

The samples collected at Moon Island reservoir contain less organic

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[illegible]

matter than those taken at Old Harbor Point. This is due partly to the removal of sludge at the deposit sewers and by sedimentation in the reservoir, and partly to the fact that the sewage, in passing from the pumping station to the reservoir, has evidently been diluted by sea water. This is shown by the larger amount of chlorine found in the sample collected at the reservoir. The increase of chlorine in the reservoir sewage would show a leakage of 4 or 5 per cent. of sea water into the sewer between the pumping station and the reservoir. Another indication of leakage and dilution is the smaller amount of free ammonia in the average reservoir sewage. On account of this loss of organic matter, and dilution, statements in the following pages as to the percentage of sewage in samples collected from the harbor will be based upon the strength of the average sewage during September, using the Old Harbor Point average for samples from the Moon Island area, and the Deer Island average for samples from the Deer Island area, unless the contrary is expressly stated.

Sewage discharged into the salt water of the harbor has a tendency to rise and mingle with the upper portions of the salt water to a much greater degree than with the deeper portions. This is due partly to the greater density of the salt water and partly to the considerable amounts of fatty matter in suspension and solution in the sewage.

Sea Water, Harbor Water, and the Water of Quincy Bay.

During the course of this investigation a number of samples have been collected just outside the harbor or near the harbor entrance, in order to determine the organic contents of this water, which is practically unpolluted. Samples were also collected between the Moon Island outlet and the Deer Island outlet, at places not usually influenced by the sewage discharged from these outlets. Other samples were collected from different points, reaching from outside Deer Island up as far as the national docks. A series of samples was also taken from various locations in Quincy Bay. The averages of the analyses of these samples are given in the following table: —

Average Analyses of Sea and Harbor Water.

[Parts per 100,000.]

LOCALITY.	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Sea water, ...	.0057	.0124	1,740
Harbor water, ...	.0139	.0132	1,681
Quincy Bay, ...	.0056	.0124	1,708

On no occasion during the days of observation, neither during continuous discharge nor during the reservoir discharge at Moon Island, has the sewage shown any tendency to flow into Quincy Bay south of a line drawn from Squantum Head across Sunken Island Beacon to Peddock's Island, and on only one occasion has it approached this line.

THE DISCHARGE OF SEWAGE AT MOON ISLAND.

When the continuous discharge of sewage from Moon Island takes place during the flood tide, the sewage is generally carried between Thompson's Island and Moon Island. When the reservoir is discharged on the ebb tide, the sewage spreads out in a broad field, curving around the upper end of Long Island and extending across just into Quincy Bay. It then passes down the harbor, usually through the channel between Long and Rainsford islands, but sometimes also passing into the channel south-east of Rainsford Island.

Buoys were placed in the harbor in front of the Moon Island outlet, before making observations or collecting samples from the harbor. These buoys were located at definite points in the area which was expected to be reached and covered by the sewage discharged from the reservoir. They were numbered from 1 to 17 as is shown on the map accompanying this report. One line of buoys extended across the outlet about 6,500 feet in the direction of the lower end of Peddock's Island; another line of about the same length extended across the first line nearly in the direction of Spectacle Island.

Many samples were collected within this area on different days, and many samples were also collected beyond or outside of this area. The details of the analyses of these samples and other information are given with the tables hereto appended.

Such examinations of the shores and bed of the harbor as have been made indicate that no serious pollution of them has resulted from the discharge of sewage, except directly around the outlet and in the small cove near the outlet; but an appreciable pollution can be noted at low tide for some distance around both sides of Moon Island and along the causeway leading to Squantum Head.

The information obtained from these observations of the sewage fields at Moon Island, from the analyses of the many samples collected at different places within and without these fields and from the examination of many samples by the eye alone, leads to the following conclusions: —

1. The area covered by a reservoir discharge of 22,000,000 gallons is approximately 750 acres.

2. This area is enlarged according to the volume of sewage allowed to run from the outlet continuously either before or after a reservoir discharge.

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3. A considerable time having elapsed after a reservoir discharge, a continuous discharge is held to a much narrower field than that occupied when 22,000,000 gallons are discharged within three-quarters of an hour.

4. When 11,000,000 gallons of sewage are allowed to run from the reservoir, and the gates are then closed, the area covered is not more than one-third what it is when 22,000,000 gallons are discharged at one time.

5. The discoloration of the field of 750 acres at times of a full discharge is plainly marked on a comparatively calm day, and is objectionable to the sense of sight over about two-thirds of the area; but the offensive odors on a calm day are confined to a relatively small portion of the area.

6. The presence of sewage is indicated at times by the presence of matters in suspension in the water for a distance of at least 1½ miles from the sewer outlet. Beyond this distance areas of sleek are sometimes visible, and occasionally areas containing distinct traces of sewage matter are seen.

7. Observations of the rate of flow show that the sewage advances somewhat faster than the tidal flow for a few hundred feet from the outlet, owing to the impetus given by the high velocity in the outlet sewer.

8. The observations and analyses show that, generally speaking, the upper two or three inches of the sewage area contain much the greater percentage of sewage for a considerable period, and that this percentage decreases from the surface downward when the area is first covered. The percentage of sewage in the lower samples becomes less as the field moves forward and expands, and the sewage becomes more and more diluted on account of the greater area covered. The percentage of sewage in the surface samples also becomes less, although we are able to trace the presence of sewage at the surface longer than at the depth of a foot or more, on account of the large amount of sewage primarily present at the surface. It is also probable that there is a continuous sedimentation of the suspended matter in the sewage from the time the sewage is first discharged. This sedimentation takes place so gradually, and in a volume of water so large, that samples collected at a depth of 5 feet seldom show the presence of sewage, either by inspection or analysis.

9. The temporary pollution of the sea water was mainly confined to the discolored area. This was usually found to have been broken up and dissipated in from two to three hours after the discharge of sewage, depending largely upon the force of the waves.

10. The large areas sometimes noticed, because covered with a thin film of grease or so-called sleek, do not contain beneath this film

enough sewage to be detected, and the film itself is hardly of appreciable thickness.

11. The most noticeable odors blown towards the land from Moon Island appear to come from the sewage in the open reservoir, and not from the sewage after it has been discharged into the harbor.

THE SEWAGE FIELD AT DEER ISLAND.

Sewage flows continuously from the outlet at Deer Island. The average volume discharged daily in September was 38,200,000 gallons, which is almost exactly one-half the average daily volume pumped to the Moon Island outlet during the same month.

The general direction in which the sewage is carried after leaving this outlet is as follows. When the tide is ebbing, the sewage runs out to sea for a large part of the time nearly in an easterly direction. When the tide is coming in, the sewage current swings slowly around. This movement, however, is somewhat delayed by the fact that the sewer outlet is on the harbor side of the bar stretching from Deer Island to Deer Island Light. As the tide enters the lower portion of the harbor and comes around the upper end of Long Island, its tendency is to keep the sewage field flowing in the direction of the lower end of Long Island until the water has risen enough to cover the bar between Deer Island and Deer Island Light. The sewage is then carried in the direction of Governor's Island.

At high water there is a sewage field lying south and west of the outfall. As the ebb tide currents start, this field moves outward over Broad Sound, and is connected with the outfall by a band of sewage varying from 50 to 250 feet in width.

Series of samples were collected and observations were made on the Deer Island sewage fields on September 2, October 4 and October 24. The details of the analyses of these samples and other information are given with the annexed tables.

A determination was made of the number of bacteria present in the sewage at the outlet, and in samples taken at the same distance from the outlet as the samples for chemical analysis. The results correspond with the chemical results, and are as follows: —

Number of Bacteria per Cubic Centimeter.

At outlet,	2,240,000
500 feet from outlet,	121,000
1,000 feet from outlet,	35,000
3,000 feet from outlet, limit of area,	1,800

The investigations of the discharge of sewage from the Deer Island outlet lead to the following conclusions: —

1. At high water there is a sewage field lying south and west of the outlet. Immediately at the outlet, sewage can be traced to a depth of about 5 feet. At the surface, in the densest part, there was about 30 per cent. of sewage. This percentage decreases rapidly as the distance from the outlet increases. At 900 feet from the outlet only a small percentage of sewage was found, and at the edge of the visible sewage field the samples were nearly normal sea water.

2. As the ebb tide currents start, this field moves outward over Broad Sound, and is followed by a narrow band of sewage from the outlet. Samples taken directly over the outlet show that this band has there a depth of about 5 feet, and that the densest part at the surface contains about 30 per cent. of sewage.

3. Samples taken at intervals of fifteen minutes show a steady decrease in the amount of sewage present, as follows: —

Percentage of Sewage in Surface Samples.

15 minutes after leaving outfall,	20
30 minutes after leaving outfall,	15
45 minutes after leaving outfall,	5
60 minutes after leaving outfall,	4

Less sewage is found below the surface, but distinct traces of it can be generally found at a depth of 2 feet.

4. The discoloration has nearly disappeared when the sewage has moved 1⅛ miles from the outlet, which takes about one and one-quarter hours. Beyond this distance only the sleek can be found, and this only on calm days. The area covered by the discolored field is about 350 acres during the ebb tide, but including the sleek the area is about 450 acres. Samples taken for analysis from the area of sleek show practically no organic matter, as the sleek itself is simply an exceedingly thin film of grease upon the surface of the water.

5. A field of sewage collects on the west side of Deer Island spit at low tide. This field extends nearly to the Deer Island shore. The discoloration can be traced for about one and one-half hours, reaching a distance of about 1 mile and covering an area of about 300 acres.

6. The odors at the Deer Island outlet are much less noticeable than at Moon Island. This difference is due to the storage of sewage in the reservoir at Moon Island, as disagreeable odors increase when sewage is stored.

CONCLUSIONS AS TO THE PROPOSED CONTINUOUS DISCHARGE OF SEWAGE NEAR PEDDOCK'S ISLAND.

1. The tidal volume passing between Rainsford Island and Long Island during the ebb tide is about 72,000 cubic feet per second, as determined by your office. A full discharge from the reservoir at Moon Island covers an area of about 750 acres while passing through this channel. When the amount of sewage discharged from the reservoir is only half the usual amount, the area covered is only about one-third as large. Reasoning from this, it seems probable that, if the volume of sewage discharged at each tide should become twice as great as the volume now discharged, the area covered by it might be at least 1,500 or 2,000 acres, and that, because of such a large discharge, a large area would remain covered with sewage for several hours. The area of dense pollution would also be correspondingly enlarged. On the other hand, the continuous flow of sewage from the Deer Island outlet is seldom more than 2,000,000 gallons per hour, and the area covered is about 450 acres. This area contains a much smaller percentage of sewage than does the Moon Island area; because there are only about 2,000,000 gallons to be distributed each hour over an area of about 450 acres at Deer Island, instead of about 22,000,000 gallons to be distributed over an area of about 750 acres at Moon Island, and because the tidal flow at the Deer Island outlet is about three and one-half times the tidal flow at the Moon Island outlet.

2. A continuous discharge of sewage from an outlet near Peddock's Island into a tidal flow of about 200,000 cubic feet per second would produce about the same effect upon the surrounding water as that produced at Deer Island, if the volume of sewage discharged were the same at each place. A discharge of several times this volume per hour would make the visible area of pollution somewhat greater; but, judging from surrounding conditions at Moon Island and at Deer Island, the hourly discharge might reach 10,000,000 gallons without causing offence to the sense of smell, except over a somewhat limited area. The volume of tidal flow would certainly not allow serious deposits of organic matters to accumulate. When the hourly discharge has become greater than this, more outlets may perhaps be needed to give the best results, as dilution with sea water, the chief factor of successful sewage disposal in this manner, would be more rapid with a greater number of outlets.

It should be understood that, at whatever point sewage may be discharged into the harbor, the constantly increasing quantity of sewage may in time reach such a volume that its diffusion in the water may become imperfect, and then noticeable odors may be produced.

ANALYSES

OF

SAMPLES COLLECTED IN BOSTON HARBOR,

BOTH WITHIN AND WITHOUT THE AREAS INFLUENCED BY THE DISCHARGE OF SEWAGE AT MOON ISLAND AND DEER ISLAND, AND OTHER INFORMATION RELATING THERETO.

Table No. 1.	Samples of sewage at Deer Island.
Table No. 2.	Samples of sewage at Old Harbor Point pumping station.
Table No. 3.	Samples of sewage at Moon Island reservoir.
Table No. 4.	Samples from the harbor.
Table No. 5.	Samples from the harbor.
Table No. 6.	Samples from the harbor.
Table No. 7.	Samples from Quincy Bay and River.
Tables Nos. 8–14.	Samples from Moon Island area.
Tables Nos. 15–17.	Samples from Deer Island area.

TABLE NO. 1. — *Series of Samples collected at Deer Island Pumping Station.*

[Chemical analysis, parts per 100,000.]

DATE.	AMMONIA.		Chlorine.	DATE.	AMMONIA.		Chlorine.
	Free.	Albuminoid.			Free.	Albuminoid.	
September 1,	1.35	.65	374	September 17,	2.85	.58	317
" 2,	1.90	.45	364	" 18,	2.00	.43	354
" 3,	2.60	.38	320	" 19,	2.25	1.17	320
" 4,	2.40	.36	360	" 20,	1.75	.74	339
" 5,	1.10	.27	344	" 21,	1.90	.81	340
" 6,	1.40	.48	311	" 22,	2.05	.99	340
" 7,	2.15	.44	275	" 23,	1.55	.61	270
" 8,	1.40	.70	289	" 24,	2.15	.61	366
" 9,	2.00	.48	282	" 25,	1.85	.50	344
" 10,	2.00	.45	300	" 26,	2.15	1.13	344
" 11,	3.40	.41	305	" 27,	1.75	.97	351
" 12,	2.50	.94	313	" 28,	3.50	1.44	380
" 13,	1.75	.75	319	" 29,	2.00	.70	386
" 14,	3.10	1.06	296	" 30,	2.50	.54	355
" 15,	3.10	1.17	335				
" 16,	2.15	.43	311	Averages,	2.15	.69	330

TABLE NO. 2. — *Series of Samples collected at Old Harbor Point Pumping Station.*

[Chemical analysis, parts per 100,000.]

DATE.	TIME.		AMMONIA.		Chlorine.
	Began 12 M.	Ended 12 M.	Free.	Albuminoid.	
September 1,	August 31,	September 1,	1.75	.52	176
" 2,	September 1,	" 2,	1.50	1.21	177
" 3,	" 2,	" 3,	1.95	.66	140
" 4,	" 3,	" 4,	2.00	.45	141
" 5,	" 4,	" 5,	2.20	.40	130
" 6,	" 5,	" 6,	2.00	.62	131
" 7,	" 6,	" 7,	2.00	.82	160
" 8,	" 7,	" 8,	1.50	.49	129
" 9,	" 8,	" 9,	1.90	.54	119
" 10,	" 9,	" 10,	1.90	.63	159
" 11,	" 10,	" 11,	6.50	.66	185
" 12,	" 11,	" 12,	2.50	.78	170
" 13,	" 12,	" 13,	2.50	.80	180
" 14,	" 13,	" 14,	2.25	.68	164
" 15,	" 14,	" 15,	2.50	.84	141
" 16,	" 15,	" 16,	2.60	.96	150
" 17,	" 16,	" 17,	2.35	.60	135
" 18,	" 17,	" 18,	2.35	.70	165
" 19,	" 18,	" 19,	2.10	.54	161
" 20,	" 19,	" 20,	2.65	.84	96
" 21,	" 20,	" 21,	2.15	.91	119
" 22,	" 21,	" 22,	2.15	1.03	156
" 23,	" 22,	" 23,	2.25	.76	106
" 24,	" 23,	" 24,	2.10	.59	130
" 25,	" 24,	" 25,	2.15	.49	269
" 26,	" 25,	" 26,	1.60	.61	170
" 27,	" 26,	" 27,	2.20	.73	191
" 28,	" 27,	" 28,	2.00	.62	195
" 29,	" 28,	" 29,	1.70	.51	160
" 30,	" 29,	" 30,	2.55	.82	147
Averages,			2.26	.69	155

Table No. 3. — *Series of Samples collected at Moon Island Reservoir.*

[Chemical analysis, parts per 100,000.]

DATE.	Time.	Ammonia.		Chlorine.
		Free.	Albuminoid.	
September 1, ...	1:00	1.10	.23	280
" 2, ...	12:00	1.30	.25	275
" 3, ...	12:00	1.10	.23	238
" 4, ...	12:00	1.20	.19	234
" 5, ...	12:00	1.20	.31	260
" 6, ...	12:00	2.40	.65	154
" 7, ...	12:00	2.85	.84	130
" 8, ...	12:00	2.00	.49	201
" 9, ...	12:00	1.90	.46	210
" 10, ...	12:00	2.60	.55	211
" 11, ...	2:00	1.25	.92	240
" 12, ...	10:00	2.55	.42	211
" 13, ...	10:00	1.15	.30	189
" 14, ...	10:00	.95	.71	180
" 15, ...	10:00	1.15	.29	194
" 16, ...	11:00	1.40	.30	201
" 17, ...	10:00	1.20	.26	250
" 18, ...	10:00	1.80	.44	215
" 19, ...	10:00	1.25	.31	261
" 20, ...	10:00	1.00	.35	345
" 21, ...	10:30	1.25	.50	274
" 22, ...	10:30	1.50	.41	289
" 23, ...	11:00	1.55	.57	140
" 24, ...	11:00	1.90	.56	344
" 25, ...	12:00	2.25	.58	320
" 26, ...	12:00	3.00	.69	250
" 27, ...	10:30	1.40	.31	231
" 28, ...	11:00	1.30	.50	216
" 29, ...	1:30	3.15	.97	184
" 30, ...	12:00	3.10	.74	165
Averages, ...		1.72	.48	230

Table No. 4. — *Series of Samples collected August 20, from Moon Island to beyond Deer Island Light.*

High Tide at 1 P.M.; Direction of Wind, North-east; Reservoir discharged at about 1:40 P.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	Ammonia.		Chlorine.
			Free.	Albuminoid.	
Station 1, ...	11:30	Surface, . .	.0290	.0196	1,565
" 1, ...	11:30	2 feet, . . .	.0168	.0218	1,614
" 1, ...	11:30	5 feet, . . .	.0260	.0182	1,604
" 2, ...	11:55	Surface, . .	.2200	.0540	1,342
" 2, ...	11:55	2 feet, . . .	.0262	.0168	1,652
" 2, ...	11:55	5 feet, . . .	.0152	.0120	1,655
" 3, ...	12:15	Surface, . .	.0234	.0146	1,605
" 3, ...	12:15	2 feet, . . .	.0128	.0128	1,675
" 3, ...	12:15	5 feet, . . .	.0180	.0144	1,680
" 4, ...	12:30	Surface, . .	.0246	.0142	1,640
" 4, ...	12:30	2 feet, . . .	.0168	.0124	1,668
" 4, ...	12:30	5 feet, . . .	.0168	.0146	1,680
" 5, ...	12:45	Surface, . .	.1284	.0436	1,550
" 5, ...	12:45	2 feet, . . .	.0258	.0196	1,670
" 5, ...	12:45	4 feet, . . .	.0114	.0116	1,701
" 6, ...	12:53	Surface, . .	.0806	.0280	1,560
" 6, ...	12:53	2 feet, . . .	.0632	.0260	1,595
" 6, ...	12:53	5 feet, . . .	.0284	.0136	1,615
" 7, ...	1:05	Surface, . .	.0042	.0106	1,656
" 7, ...	1:05	2 feet, . . .	.0080	.0182	1,665
" 7, ...	1:05	5 feet, . . .	.0064	.0136	1,670

TABLE NO. 5. — *Series of Samples collected August 23, from Outside Deer Island up to National Docks.*

Flood Tide; High Tide at 3:15 P.M.; Direction of Wind, South-west.

[Chemical analysis, parts per 100,000.]

STATION.	Depth.	AMMONIA.		Chlorine.
		Free.	Albuminoid.	
Station 1,	Surface,	.0102	.0130	1,680
" 1,	2 feet,	.0066	.0114	1,691
" 1,	5 feet,	.0110	.0118	1,723
" 2,	Surface,	.0200	.0232	1,718
" 2,	2 feet,	.0066	.0106	1,717
" 2,	5 feet,	.0096	.0094	1,720
" 3,	Surface,	.1980	.0502	1,655
" 3,	2 feet,	.1882	.0438	1,643
" 3,	5 feet,	.0634	.0230	1,660
" 4,	Surface,	.0062	.0110	1,680
" 4,	2 feet,	.0104	.0108	1,692
" 4,	5 feet,	.0114	.0136	1,698
" 5,	Surface,	.0242	.0154	1,705
" 5,	2 feet,	.0116	.0126	1,704
" 5,	5 feet,	.0106	.0146	1,697
" 6,	Surface,	.0198	.0172	1,650
" 6,	2 feet,	.0152	.0106	1,655
" 6,	5 feet,	.0150	.0110	1,655
" 7,	Surface,	.0260	.0130	1,584
" 7,	2 feet,	.0188	.0118	1,600
" 7,	5 feet,	.0164	.0124	1,610

TABLE NO. 6. — *Series of Samples collected September 7, from Outside Deer Island to National Docks.*

Ebb Tide; High Tide at 4:23 P.M.; Direction of Wind, South.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.		Chlorine.
			Free.	Albuminoid.	
Station 1,	7:45	Surface,	.0030	.0124	1,754
" 1,	7:45	2 feet,	.0042	.0116	1,775
" 1,	7:45	5 feet,	.0048	.0140	1,776
" 2,	8:10	Surface,	.0030	.0154	1,770
" 2,	8:10	2 feet,	.0066	.0138	1,754
" 2,	8:10	5 feet,	.0056	.0136	1,754
" 3,	8:30	Surface,	.0064	.0110	1,748
" 3,	8:30	2 feet,	.0058	.0138	1,750
" 3,	8:30	5 feet,	.0116	.0134	1,750
" 4,	9:05	Surface,	.0118	.0148	1,731
" 4,	9:05	2 feet,	.0064	.0138	1,721
" 4,	9:05	5 feet,	.0062	.0132	1,729
" 5,	9:30	Surface,	.0076	.0110	1,757
" 5,	9:30	2 feet,	.0072	.0114	1,735
" 5,	9:30	5 feet,	.0072	.0126	1,731
" 6,	9:50	Surface,	.0096	.0128	1,727
" 6,	9:50	2 feet,	.0092	.0126	1,704
" 6,	9:50	5 feet,	.0126	.0148	1,718
" 7,	10:20	Surface,	.0230	.0152	1,565
" 7,	10:20	2 feet,	.0232	.0142	1,572
" 7,	10:20	5 feet,	.0222	.0152	1,570

TABLE NO. 7. — *Series of Samples collected August 17, from Quincy Bay and River.*

High Tide at 5:16 P.M.; Direction of Wind, South-west.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.		Chlorine.
			Free.	Albuminoid.	
Station 1,	11:30	Surface,	.0064	.0148	1,728
" 1,	11:30	2 feet,	.0064	.0136	1,699
" 1,	11:30	5 feet,	.0066	.0150	1,734
" 2,	12:10	Surface,	.0150	.0142	1,538
" 2,	12:10	2 feet,	.0040	.0150	1,584
" 2,	12:10	5 feet,	.0066	.0144	1,636
" 3,	11:30	Surface,	.0026	.0122	1,731
" 3,	11:30	2 feet,	.0026	.0140	1,721
" 3,	11:30	5 feet,	.0032	.0142	1,718
" 4,	11:40	Surface,	.0040	.0122	1,718
" 4,	11:40	2 feet,	.0034	.0124	1,725
" 4,	11:40	5 feet,	.0066	.0174	1,716
" 5,	12:55	Surface,	.0036	.0112	1,724
" 5,	12:55	2 feet,	.0172	.0102	1,718
" 5,	12:55	5 feet,	.0040	.0116	1,748
" 6,	1:00	Surface,	.0040	.0096	1,739
" 6,	1:00	2 feet,	.0072	.0098	1,727
" 6,	1:00	5 feet,	.0036	.0092	1,740
" 7,	1:15	Surface,	.0034	.0098	1,747
" 7,	1:15	2 feet,	.0042	.0112	1,757
" 7,	1:15	5 feet,	.0030	.0088	1,728

TABLE NO. 8. — *Series of Samples collected June 1, from Moon Island Area.*

High Tide at 8:01 A.M.; Direction of Wind, North-east; Reservoir Discharge began at about 8:40 A.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	AMMONIA.		Chlorine.
		Free.	Albuminoid.	
Station 1,	8:50	.0280	.0880	1,709
" 1,	10:03	.1000	.0680	1.673
" 2,	8:55	.0720	.0800	1,676
" 2,	9:50	.0200	.0360	1,699
" 3,	8:44	.0120	.0680	1,669
" 3,	9:43	.0120	.0520	1,650
" 4,	9:40	.0120	.0920	1,638
" 5,	8:30	.0260	.0360	1,656
" 5,	9:43	.1400	.1360	1,441
" 5,	10:13	.1200	.0880	1,431
" 6,	8:45	.2840	.1200	1,452
" 6,	10:00	.2400	.2280	1,440
" 7,	7:30	.2120	.1680	1,468
" 7,	8:40	.0720	.0880	1,621
" 7,	10:00	.2240	.2240	1,180
" 7,	10:27	.1000	.1360	1,490
" 8,	6:35	.0680	.0920	1,619
" 8,	10:00	.1400	.1360	1,400
" 9,	8:30	.0720	.0720	1,648
" 9,	10:00	.0240	.0640	1,570
" 10,	8:30	.0080	.0400	1,672
" 10,	9:44	.1400	.1440	1,460
" 10,	10:15	.1080	.0560	1,509
" 11,	8:30	.1520	.0640	1,668
" 11,	9:46	.0120	.0560	1,619
" 11,	10:19	.0520	.0920	1,589
" 12,	8:30	.0400	.0680	1,650
" 12,	9:50	.0440	0680	1,612
" 12,	10:11	.1820	.1000	1,458
" 13,	8:30	.0800	.0560	1,580
" 13,	9:52	.0720	.1720	1,639
" 14,	9:50	.0280	.0920	1,680

The analyses given in Table No. 8 are from samples collected off Moon Island, from stations 1 to 14 inclusive. The samples were collected as near to the surface as was possible. Every sample collected on this day showed upon analysis the presence of a considerable amount of sewage. The first sample was taken before the reservoir discharge, and the traces of sewage found in it were evidently due to a previous discharge of sewage. Samples taken immediately after the reservoir discharge, from the area included by stations 1 to 14, about 1,000 acres, showed a considerable percentage of sewage. Some of them contained 30 per cent. as much organic matter as the average sewage of September. Those taken one hour and forty-five minutes after the beginning of the reservoir discharge showed that there was still an appreciable amount of sewage in the water over nearly the entire area. The amount of sewage discharged during the entire day was about 100,000,000 gallons; and, as the reservoir capacity at that time was only about 22,000,000 gallons, it is evident that there must have been a continuous discharge during part of the day.

TABLE NO. 9. — *Series of Samples collected June 9, from Moon Island.*

High Tide at 3:15 P.M.; Direction of Wind, North-west; Reservoir discharged at about 3:45 P.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	AMMONIA.		Chlorine.
		Free.	Albuminoid.	
Station 1,	3:45	.1360	.1240	1,680
" 1,	5:00	.1240	.1200	1,480
" 1,	5:45	.0920	.1360	1,458
" 1,	6:45	.1520	.1040	1,338
" 2,	3:45	.0320	.0640	1,658
" 2,	5:00	.2340	.1320	1,369
" 2,	5:45	.2200	.1400	1,290
" 3,	3:45	.3160	.1640	1,429
" 3,	5:00	.2440	.1280	1,370
" 3,	5:45	.2200	.1720	1,218
" 4,	3:45	.1200	.2160	1,394
" 4,	5:00	.3200	.1720	1,318
" 4,	5:45	.2400	.1520	1,230
" 5,	3:45	.3400	.1680	1,392
" 5,	4:10	.2720	.1600	1,392
" 5,	5:05	.1240	.1520	1,450
" 5,	5:50	.3200	.1480	1,136
" 6,	3:45	.7200	.1920	1,178
" 6,	5:00	.2960	.1400	1,256
" 6,	5:00	.0920	.1000	1,469
" 6,	5:00	.0280	.0680	1,602
" 6,	6:00	.4000	.1520	1,170
" 7,	3:45	.8800	.2960	917
" 7,	5:00	.3960	.1890	1,169
" 8,	3:45	.6000	.2880	1,178
" 8,	5:00	.1660	.1040	1,310
" 8,	6:00	.4600	.2800	992
" 9,	3:45	.0440	.0720	1,620
" 9,	5:00	.0200	.0360	1,580
" 9,	6:00	.0320	.0600	1,559
" 9,	7:00	.0200	.0560	1,530
" 10,	4:15	.8400	.3360	938

TABLE NO. 9 — *Concluded.*

[Chemical analysis, parts per 100,000.]

STATION.	Time.	AMMONIA.		Chlorine.
		Free.	Albuminoid.	
Station 10,	5:05	.4600	.1800	1,408
" 10,	5:55	.1480	.1080	1,367
" 11,	4:25	.0400	.0720	1,571
" 11,	5:00	.1000	.0760	1,402
" 11,	6:00	.0080	.0720	1,508
" 11,	6:45	.0320	.0920	1,520
" 12,	4:05	.1040	.0880	1,592
" 12,	5:10	.0960	.0760	1,540
" 12,	5:45	.1420	.0960	1,472
" 13,	4:00	.0680	.0760	1,618
" 13,	5:20	.0520	.1120	1,659
" 13,	5:45	.4120	.1600	1,641
" 13,	6:55	.1000	.0760	1,648
" 14,	3:50	.1280	.0720	1,819
" 14,	4:30	.0240	.0920	1,616
" 14,	6:10	.0720	.0720	1,644
" 15,	4:00	.0280	.0600	1,599
" 15,	5:00	.0260	.0720	1,652
" 15,	6:05	.0160	.0641	1,627
" 15,	7:00	.0280	.0560	1,653
" 16,	4:05	.0280	.0440	1,607
" 16,	4:45	.0230	.0840	1,620
" 16,	6:15	.0280	.0920	1,628
" 17,	3:45	.0320	.0840	1,650
" 17,	5:10	.0240	.0440	1,650
" 17,	6:00	.0440	.0440	1,641

The analyses given in Table No. 9 are from samples collected off Moon Island, as near the surface as possible. Some of these samples were taken from stations 14, 15, 16 and 17, nearer Quincy Bay than any samples collected during the previous series.

A sample was collected at each station about thirty minutes before the discharge from the reservoir began; others were collected at each station, fifteen minutes, one hour, and from the edge of the area one and one-half hours, after the beginning of the reservoir discharge. They show that before the reservoir discharge the sewage field extended over the entire area covered by these stations, and also a considerable distance beyond station 1. This was due to a previous continuous discharge. Where the area was plainly marked and dense, the surface water contained from 10 to 25 per cent. of sewage. This percentage increased considerably after the reservoir discharge, until the surface water over a portion of the area contained from 30 to 40 per cent. as much organic matter as the average September sewage. The area covered on this day was about 800 acres. The reservoir was discharged at 5 : 30 P.M. and the last samples were collected about 7 P.M.; and at this hour the surface water over almost the entire area contained about 11 per cent. of sewage.

TABLE NO. 10. — *Series of Samples collected June 16, from Moon Island Area.*

High Tide at 9:36 A.M.; Direction of Wind, East; Reservoir discharged at about 10:15 A.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.		Chlorine.
			Free.	Albuminoid.	
Station 1,	12:55	Surface,	.0520	.0380	1,578
" 1,	12:55	1 foot,	.0720	.0300	1,620
" 1,	2:35	Surface,	.0260	.0440	1,620
" 1,	2:35	1 foot,	.0280	.0260	1,632
" 2,	12:50	Surface,	.0340	.0360	1,587
" 2,	12:50	1 foot,	.1200	.0340	1,631
" 3,	12:50	Surface,	.0340	.0320	1,622
" 3,	12:50	1 foot,	.0340	.0380	1,595
" 3,	2:10	1 foot,	.0360	.0360	1,712
" 4,	12:50	Surface,	.0220	.0300	1,527
" 4,	12:50	1 foot,	.0160	.0380	1,575
" 5,	12:40	Surface,	.3500	.1120	1,360
" 5,	12:40	1 foot,	.0840	.0700	1,478
" 5,	3:55	Surface,	.0100	.0280	1,620
" 5,	3:55	1 foot,	.0100	.0280	1,652
" 6,	12:40	Surface,	.0400	.0520	1,531
" 6,	12:40	1 foot,	.0720	.0500	1,500
" 7,	12:40	Surface,	.1540	.0660	1,415
" 7,	12:40	1 foot,	.1340	.0600	1,525
" 7,	4:05	Surface,	.0160	.0360	1,672
" 7,	4:05	1 foot,	.1220	.0340	1,604
" 8,	12:35	Surface,	1.1600	.2440	942
" 8,	12:35	1 foot,	.0420	.0440	1,528
" 9,	12:35	Surface,	.0100	.0200	1,558
" 12,	2:05	Surface,	.0500	.0360	1,620
" 12,	2:05	1 foot,	.0500	.0360	1,625
" 13,	2:10	Surface,	.0080	.0260	1,652
" 14,	2:00	Surface,	.0060	.0200	1,643
" 14,	2:00	1 foot,	.0060	.0340	1,642
" 15,	1:30	Surface,	.0100	.0200	1,670
" 15,	1:30	1 foot,	.0120	.0320	1,690
" 15,	1:30	6 feet,	.0100	.0300	1,612
" 16,	1:35	Surface,	.0040	.0420	1,628
" 16,	1:35	1 foot,	.0600	.0420	1,600

TABLE NO. 10 — *Concluded.*

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	AMMONIA.		Chlorine.
				Free.	Albuminoid.	
Station 1,	Off Moon Island, in sewage area,	11:30	Surface,	.0800	.0620	1,560
" 2,	Off Moon Island, outside sewage area,	11:30	Surface,	.0100	.0220	1,665
" 3,	Quincy Bay,	11:45	Surface,	.0220	.0300	1,653
" 4,	Quincy Bay,	11:45	1 foot,	.0100	.0180	1,663
" 5,	Middle of Quincy Bay,	11:55	Surface,	.0040	.0200	1,600
" 6,	Middle of Quincy Bay,	11:55	1 foot,	.0100	.0200	1,630
" 7,	Middle of Quincy Bay,	11:55	6 feet,	.0280	.0320	1,665
" 8,	Quincy Bay,	12:05	Surface,	.0040	.0260	1,665
" 9,	Quincy Bay,	12:05	1 foot,	.0060	.0300	1,662
" 10,	Near Quarantine Rocks, outside sewage area,	12:15	Surface,	.0060	.0260	1,625
" 11,	Near Quarantine Rocks, within sewage area,	12:18	Surface,	.0200	.0640	1,625
" 12,	Between Rainsford and Long islands,	2:50	Surface,	.0060	.0340	1,648
" 13,	Off Spar Buoy No. 3,	3:00	Surface,	.0280	.0200	1,665
" 14,	Between Fort Warren and Rainsford Island, within sewage area,	3:07	Surface,	.0100	.0200	1,634
" 15,	Between Fort Warren and Rainsford Island, outside sewage area,	3:10	Surface,	.0060	.0100	1,640

The volume of sewage pumped to Moon Island on June 16 was about 86,000,000 gallons, or 21,000,000 gallons more at each tide than the reservoir capacity. The analyses show that traces of sewage could be found at many of the stations two hours and twenty minutes after the beginning of the reservoir discharge, but the observations showed that this area was nearly free from sewage thirty minutes later. Samples were taken when the area was fairly clean from sewage particles in suspension, to ascertain what percentage of organic matter would be shown by chemical analyses. Samples taken between Rainsford and Long islands, off Spar Buoy No. 3, in the sewage area, and between Fort Warren and Rainsford Island, in the sewage area, contained more than twice the organic matter found in a sample taken outside the sewage area, between Fort Warren and Rainsford Island. These special samples, taken at the extreme limits of the sewage area, contained but a small amount of sewage, — not more than 3 to 5 per cent. as much organic matter as the average sewage of September. Samples taken at the edge of Quincy Bay showed a very slight increase of organic matter over that found in normal harbor water.

TABLE No. 11.— *Series of Samples collected June 23, from Moon Island Area.*

High Tide at 1:59 P.M.; Direction of Wind, West; Reservoir Discharge began at 2:25 P.M., and ended at 2:59 P.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.	
			Free.	Albuminoid.
Station 1,	1:45	Surface,	.0120	.0220
" 1,	3:52	Surface,	.0020	.0220
" 1,	3:52	1 foot,	.0400	.0400
" 3,	2:00	Surface,	.0200	.0400
" 3,	3:59	Surface,	.0120	.0400
" 3,	3:59	1 foot,	.0140	.0220
" 5,	1:10	Surface.	.0140	.0300
" 5,	3:35	Surface,	.2980	.1040
" 5,	3:35	1 foot,	.1440	.0600
" 8,	1:10	Surface,	.0120	.0440
" 8,	3:40	Surface,	.3680	.1240
" 8,	3:40	1 foot,	.2480	.1100
" 9,	1:05	Surface,	.0080	.0360
" 9,	3:50	1 foot,	.0400	.0660
" 10,	3:10	Surface,	.0240	.0180
" 10,	3:10	2 feet,	.0240	.0340
" 10,	3:10	4 feet,	.0020	.0640
" 10,	3:30	Surface,	.1680	.0780
" 10,	3:30	2 feet,	.1680	.0700
" 10,	3:30	4 feet,	.1020	.0740
" 11,	2:10	Surface,	.0040	.0240
" 11,	3:29	Surface,	.0140	.0220
" 11,	3:29	1 foot,	.0180	.0260
" 12,	1:06	Surface,	.0120	.0300
" 12,	3:39	Surface,	.1400	.0620
" 12,	3:39	1 foot,	.0880	.0600
" 12,	3:50	Surface,	.0940	.0460
" 12,	3:50	3 feet,	.0260	.0340
" 12,	3:50	5 feet,	.0200	.0240
" 12,	4:30	Surface,	.0120	.0260
" 12,	4:30	3 feet,	.0080	.0440

TABLE No. 11 — *Concluded.*

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.	
			Free.	Albuminoid.
Station 12, ...	4:30	5 feet, ...	.0080	.0160
" 13, ...	3:45	Surface, . . .	.0120	.0320
" 13, ...	3:45	3 feet, ...	.0080	.0200
" 13, ...	3:45	5 feet, ...	.0040	.0220
" 13, ...	4:10	Surface, . . .	.0040	.0340
" 13, ...	4:10	3 feet, ...	.0120	.0200
" 13, ...	4:10	5 feet, ...	.0020	.0240
" A,*	1:40	Surface, . . .	.0120	.0280
" B,†	1:45	Surface, . . .	.0040	.0400
" D,‡	1:50	Surface, . . .	.0100	.0180
" E,§	2:00	Surface, . . .	.0060	.0240
" E,§	2:00	3 feet, ...	·0080	.0240

* Off lower end of Rainsford Island.
† Half way between Long and Rainsford islands.
‡ Off Long Island.
§ Off upper end of Long Island.

Some of the samples of which analyses are given in Table No. 11 were collected before the reservoir discharge and some were collected afterwards. The reservoir discharge on this day was from 2:25 to 2:59 P.M. Samples were collected before the reservoir discharge in places along the channel between Long and Rainsford islands, where the water was only slightly colored by sewage, and also where it was apparently only sea water. Small sewage fields were observed in places, with open spaces of clear water between. These were undoubtedly due to a previous discharge, which had become broken up by the waves and currents. Particular care was again taken to observe how far the sewage extended into Quincy Bay. A number of samples were taken from Stations 12 and 13. These samples were taken at different times and at different depths, and none of them contained more than 6 or 7 per cent. as much organic matter as the average September sewage. Deducting the amount of organic matter in normal harbor water, the amount of organic matter due to sewage was not more than 2 or 3 per cent. of the organic matter in the average September sewage. Samples taken forty to sixty minutes after the end of the reservoir discharge showed that the main body of sewage had passed on, and had become mixed with the harbor water to such an extent that only a small area around the outlet contained any considerable percentage of sewage one hour after the discharge.

TABLE NO. 12. — *Series of Samples collected August 29, from Moon Island Area.*

High Tide at 8:59 A.M.; Direction of Wind, South-east; Reservoir Discharge began at 9:31 A.M.

[Chemical analysis, parts per 100,000.]

STATION.	Time.	Depth.	AMMONIA.		Chlorine.
			Free.	Albuminoid.	
Station A, ...	11:45	Surface, . .	.0230	.0198	1,645
" A, ...	11:45	2 feet, . . .	.0108	.0132	1,674
" A, ...	11:45	5 feet, . . .	.0124	.0122	1,662
" A, ...	12:55	Surface, . .	.0246	.0258	1,634
" B, ...	11:55	Surface, . .	.0298	.0260	1,628
" B, ...	11:55	2 feet, . . .	.0172	.0148	1,654
" C, ...	12:10	Surface, . .	.0056	.0096	1,688
" D, ...	12:30	Surface, . .	.0036	.0116	1,700
" 5, ...	11:30	Surface, . .	.1342	.0418	1,485
" 5, ...	11:30	2 feet, . . .	.0360	.0192	1,614
" 5, ...	11:30	5 feet, . . .	.0078	.0142	1,675
" 5, ...	11:30	8 feet, . . .	.0074	.0138	1,693
" 5, ...	1:15	Surface, . .	.0160	.0150	1,651
" 5, ...	1:15	2 feet, . . .	.0154	.0150	1,660
" 7, ...	11:15	Surface, . .	.3200	.1460	1,218
" 7, ...	11:15	2 feet, . . .	.0162	.0134	1,618
" 7, ...	11:15	5 feet, . . .	.0080	.0250	1,674
" 7, ...	1:25	Surface, . .	.0204	.0150	1,625
" 7, ...	1:25	2 feet, . . .	.0156	.0128	1,618

The discharge from the reservoir on August 29 began at 9:31 A.M. and was finished about 10:45 A.M. The first samples were collected at 11:15 A.M. from Station 7, while the continuous discharge which followed the reservoir discharge was in progress. The surface amount contained a distinct amount of sewage, that taken at a depth of 2 feet contained very much less, and the sample taken at 5 feet was normal harbor water. Samples were collected at 11:30 A.M. from Station 5, about 1,500 feet east of Station 7. The surface sample from Station 5 contained much less sewage than the surface sample collected at Station 7. The sample at 2 feet contained a slight trace of sewage, but the sample at 5 feet depth was normal harbor water. When the samples were collected from Station 5, the reservoir discharge had practically passed by this point; but a narrow band of sewage, due to the continuous discharge, was flowing across the area. Samples collected at Station 5 at 1:15 P.M. and at Station 7 at 1:25 P.M. showed only very slight traces of sewage.

Samples were also collected on this day at Stations A, B, and D, outside the area of marked sewage pollution, but within the area of sleek, and at Station C, which appeared to be in clear sea water. None of these samples contained much organic matter, but those collected within the area of sleek contained three or four times as much organic matter as the sea water sample. The area of distinctly marked pollution upon this day was about 763 acres.

Table No. 13. — *Series of Samples collected September 14, from Moon Island.*

High Tide at 10 A.M.; Direction of Wind, South-east; Reservoir discharged at 10 A.M.

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	Ammonia.		Chlorine.
				Free.	Albuminoid.	
Station 1, .	300 feet from outlet, . .	10:30	Surface, .	.5100	.1700	897
" 1, .	300 feet from outlet, . .	10:30	2 feet, .	.0212	.0192	1,688
" 1, .	300 feet from outlet, . .	10:30	3½ feet, .	.0158	.0138	1,683
" 1, .	300 feet from outlet, . .	10:30	5 feet, .	.0118	.0154	1,720
" 2, .	1,200 feet from outlet, . .	10:20	Surface, .	.2000	.0972	1,364
" 2, .	1,200 feet from outlet, . .	10:20	2 feet, .	.1572	.0732	1,502
" 2, .	1,200 feet from outlet, . .	10:20	3½ feet, .	.1768	.0864	1,477
" 2, .	1,200 feet from outlet, . .	10:20	5 feet, .	.0280	.0238	1,692
" 3, .	2,000 feet from outlet, . .	11:00	Surface, .	.1804	.0880	1,425
" 3, .	2,000 feet from outlet, . .	11:00	2 feet, .	.0494	.0336	1,660
" 3, .	2,000 feet from outlet, . .	11:00	3½ feet, .	.0116	.0162	1,720
" 3, .	2,000 feet from outlet, . .	11:30	Surface, .	.0932	.0480	1,581
" 3, .	2,000 feet from outlet, . .	11:30	2 feet, .	.0868	.0432	1,601
" 3, .	2,000 feet from outlet, . .	11:40	Surface, .	.0112	.0122	1,720
" 4, .	3,000 feet from outlet, . .	11:50	Surface, .	.0180	.0200	1,700

Arrangements were made with those in charge of the Moon Island reservoir to discharge on September 14 only about one-half the usual volume of sewage, in order that a comparison might be made of the relative areas of sewage fields produced by two different volumes of sewage, one of which should be twice as large as the other.

The rate at which the sewage advanced was shown by a collection of samples at the edge of the area when it reached certain definite points. The discharge from the reservoir was approximately at high water, instead of one hour after high water. No sewage was discharged continuously on this day between this reservoir discharge and the previous one, which took place four and one-half hours after the previous high tide.

The sewage reached a point about 1,200 feet from the outlet at 10:20 A.M., and samples were collected at the surface and at depths of 2, 3½ and 5 feet just after the sewage had passed this point. The surface sample contained about 20 per cent. of sewage. Those taken at 2, 3½ and 5 feet showed less organic matter, and the sample at 5 feet contained little more organic matter than normal harbor water.

Immediately after taking these samples, others were taken 300 feet from the outlet and at the same depths as before. This surface sample contained much more organic matter than the surface sample collected at a distance of 1,200 feet from the outlet; but the samples collected at depths of 2, 3½ and 5 feet contained little if any more organic matter than is normally present in the harbor water. A third series of samples was taken at 11 A.M., at the edge of the sewage area, which had then reached nearly to Station 5, 3,000 feet from the outlet.

The surface sample at this place contained about the same amount of organic matter as the surface sample collected 1,200 feet from the outlet; but the samples from depths of 2 and 3½ feet showed very much less organic matter than the samples collected at the same depths 1,200 feet from the outlet. A fourth series was taken at 11 : 30 A.M. at the edge of the area, when it had reached Station 4. Both the surface sample and one taken at a depth of 2 feet contained about three times as much organic matter as normal harbor water, and were slightly turbid.

The sewage seemed to become thoroughly mixed with the harbor water, and to be dissipated at about this time. Samples taken near Stations 3 and 2 showed little if any sewage present. The discharge did not reach these stations in sufficient strength to be observed, although it was carefully watched for.

The sewage from a half discharge of about 11,000,000 gallons on this day covered a plainly marked area of 236 acres, and reached a distance of about 4,000 feet from the outlet before being so mixed with sea water as to become unrecognizable.

TABLE NO. 14. — *Series of Samples collected October 13, from Moon Island.*

High Tide at 9:19 A.M.; Direction of Wind, East; Reservoir discharged at about 10 A.M.

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	AMMONIA.		Chlorine.
				Free.	Albuminoid.	
Station 1, .	900 feet from outlet, . .	10:25	Surface, .	.1752	.1412	1,432
" 1, .	900 feet from outlet, . .	10:25	2 feet, .	.1188	.0952	1,530
" 1, .	900 feet from outlet, . .	10:25	5 feet, .	.0196	.0490	1,789
" 2, .	1,800 feet from outlet, . .	10:40	Surface, .	.2324	.1156	1,408
" 2, .	1,800 feet from outlet, . .	10:40	2 feet, .	.1336	.0904	1,508
" 2, .	1,800 feet from outlet, . .	10:40	5 feet, .	.0332	.0462	1,680
" 3, .	2,000 feet from outlet, . .	10:58	Surface, .	.2600	.0880	1,384
" 3, .	2,000 feet from outlet, . .	10:58	2 feet, .	.1072	.0608	1,563
" 3, .	2,000 feet from outlet, . .	10:58	5 feet, .	.0188	.0178	1,718
" 4, .	4,500 feet from outlet, . .	11:15	Surface, .	.1588	.0852	1,485
" 4, .	4,500 feet from outlet, . .	11:15	2 feet, .	.0630	.0386	1,638
" 4, .	4,500 feet from outlet, . .	11:15	5 feet, .	.0124	.0204	1,740
" 5, .	7,000 feet from outlet, . .	11:35	Surface, .	.1180	.0628	1,550
" 5, .	7,000 feet from outlet, . .	11:35	2 feet, .	.0284	.0212	1,684
" 6, .	10,000 feet from outlet, . .	12:00	Surface, .	.0408	.0276	1,688
" 6, .	10,000 feet from outlet, . .	12:00	2 feet, .	.0206	.0194	1,730
" 6, .	Middle of area, near float, .	12:10	5 feet, .	.0192	.0248	1,742
" 6, .	At float, ...	12:20	Surface, .	.0592	.0400	1,598

The volume of sewage discharged on October 13 was about double the amount discharged on September 14.

The first set of samples was collected at 10 : 21 A.M., 900 feet from the outlet, when the sewage had just passed that spot. The surface sample contained about 22 per cent. of sewage, the sample from a depth of 2 feet about 15 per cent., and that from a depth of 5 feet about 7 per cent.

A second set of samples was collected at 10 : 40 A.M., 1,800 feet from the outlet, when the edge of the sewage area had just passed this point. The samples collected here contained slightly less organic matter than those collected 900 feet from the outlet, although the presence of sewage was still plain in the sample collected at a depth of 5 feet.

A third set was collected at 10 : 58 A.M., when the sewage had just passed the end of Long Island, about 2,500 feet from the outlet. The surface sample and that collected at a depth of 2 feet contained a very noticeable amount of organic matter, but that collected at a depth of 5 feet was practically normal harbor water. The edge of the sewage had reached the head buoy near Station 5 at 11 : 05.

A fourth set was taken at 11 : 15 A.M., near Station 2, when the sewage had just passed this point. The surface sample contained about the same amount of organic matter as the surface sample of the third set. The sample from a depth of 2 feet contained slightly less than the sample collected at this depth in the third series, and the sample taken at 5 feet was normal harbor water.

A fifth set was collected at 11 : 35 A.M., 7,000 feet from the outlet, when the edge of the area had just reached this location. The surface sample and that from a depth of 2 feet showed distinct sewage pollution.

A sixth set was taken at 12 M., in the edge of the area, fully 10,000 feet from the outlet. The samples taken here showed very little increase in organic matter above normal harbor water, except that the free ammonia was considerably higher. The water was passing rapidly through this channel and was plainly colored with sewage, but this color seemed to disappear within a few feet of this point. The sewage passed on both sides of Rainsford Island on this day, and samples collected at about the same distance from the outlet showed about the same amount of organic matter in either channel.

A float was thrown out at 10 : 20 A.M., directly after the beginning of the reservoir discharge. The edge of the sewage was 100 feet ahead of the float at 10 : 30 A.M. When the sewage had reached 1,800 feet from the outlet, at 10 : 40 A.M., the float was about 450 feet behind the edge of the sewage area ; at 10 : 58 A.M. the float was about 600 feet behind the edge of the sewage. At the time of the collection of the last samples, when the sewage was disappearing and becoming lost to observation, the float was still about 600 feet behind the edge of the area. About 750 acres were covered by the discharge.

TABLE NO. 15. — *Series of Samples collected September 2, from Deer Island.*

High Tide at 12:25 P M.; Direction of Wind, East.

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	AMMONIA.		Chlorine.
				Free.	Albuminoid.	
Station 1, .	At outlet, ...	11:10	Surface,	.2800	.1000	1,312
" 1, .	At outlet, ...	1:45	5 feet, .	.0110	.0146	1,789
" 1, .	At outlet, ...	1:45	Surface,	.5000	.1900	1,494
" 1, .	At outlet, ...	1:45	2 feet, .	.4300	.1540	1,562
" 2, .	100 feet from outlet, ...	-	Surface,	.0748	.0322	1,632
" 2, .	100 feet from outlet, ...	-	2 feet, .	.0306	.0218	1,722
" 2, .	100 feet from outlet, ...	-	5 feet, .	.0068	.0192	1,780
" 3, .	900 feet from Deer Island Light,	-	Surface,	.0310	.0222	1,770
" 3, .	900 feet from Deer Island Light,	-	2 feet, .	.0200	.0178	1,778
" 4, .	1,800 feet from Deer Island Light,	-	Surface,	.0132	.0130	1,780
" 5, .	One-third way from Red Buoy No. 4 to Deer Island Light, . .	-	Surface,	.0072	.0138	1,726
" 6, .	At limit of visible area of sleek, .	-	Surface,	.0056	.0082	1,789
" 6, .	Red Buoy No. 4, ...	-	Surface,	.0074	.0066	1,776
" 7, .	Straight line between Boston Light and Deer Island Light, . .	-	Surface,	.0136	.0132	1,780

High water on September 2 was at 12 : 30 P.M. The first five stations, those at the outlet, and 100, 900, 1,800 and 3,000 feet from the outlet, were considered to be on a line extending through the densest part of the sewage field. At only 100 feet from the outlet the surface sample contained but .0748 parts free, and .0322 parts albuminoid ammonia. The samples taken at depths of 2 and 5 feet contained proportionately less. At 900 feet from the outlet slight traces of the sewage were found at the surface, and at a depth of 2 feet; but at 1,800 feet from the outlet, sewage was hardly to be perceived, even by the thin layer of sleek. The volume of sewage discharged on this day was about 40,000,000 gallons, and the area covered when the samples were taken was about 350 acres.

TABLE NO. 16. — *Series of Samples collected October 4, from Deer Island Area.*

High Tide at 2:11 P.M.; Direction of Wind, West.

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	AMMONIA.		Chlorine.
				Free.	Albuminoid.	
Station 1, . .	At outfall, . .	2:05	- -	1.2000	.6400	1,315
" 2, . .	Near float, . .	2:20	Surface, .	.2284	.1484	1,636
" 2, . .	Near float, . .	2:20	2 feet, . .	.0286	.0294	1,734
" 3, . .	Near float, . .	2:35	Surface, .	.1848	.0972	1,680
" 3, . .	Near float, . .	2:35	2 feet, . .	.0342	.0316	1,705
" 4, . .	Near float, . .	2:50	Surface, .	.1032	.0576	1,709
" 4, . .	Near float, . .	2:50	2 feet, . .	.0508	.0292	1,726
" 5, . .	Near float, . .	3:05	Surface, .	.0350	.0312	1,722
" 5, . .	Near float, . .	3:05	2 feet, . .	.0180	.0260	1,740
" 6, . .	Near float, . .	3:20	Surface, .	.0282	.0210	1,739

High tide on October 4 was some minutes earlier than 1 : 56 P.M., the time given in the tide tables. A float was thrown out at the outlet at 2 : 05 P.M., and a sample was taken at the same time and place. The analysis of this sample showed that it contained more organic matter than the sample collected at the outlet on September 2. The reason for this might be merely that this sample was taken more nearly in the thread of the current. The float on this day followed almost a direct line from Deer Island Light to Boston Light. Samples were collected near the float, at the surface, and at a depth of 2 feet, at fifteen-minute intervals during one hour and fifteen minutes. When the float had travelled fifteen minutes, and was about $\frac{1}{4}$ of a mile from the outlet, the surface sample contained only 20 per cent. as much organic matter as the sample taken directly over the outlet, and there was a steady decrease in the organic matter from this point onward. One hour after the float was thrown out it had moved $\frac{7}{8}$ of a mile from the outlet. The sample taken at the surface at this place contained more organic matter than was found in the sample taken on this day outside the sewage area, but there was little if any difference in the appearance of these two samples, when seen in glass bottles.

TABLE NO. 17.—*Series of Samples collected October 24, from Deer Island Area.*

High Tide at 6 : 22 A.M.; Direction of Wind, South-west.

[Chemical analysis, parts per 100,000.]

STATION.	Location.	Time.	Depth.	AMMONIA.		Chlorine.
				Free.	Albuminoid.	
Station 1, . .	At outlet, ...	1 : 50	Surface,	1.6800	.9840	731
" 2, . .	500 feet from outlet, .	2 : 35	Surface,	.4300	.2100	1,445
" 2, . .	500 feet from outlet, .	2 : 35	2 feet, .	.0904	.0832	1,647
" 3, . .	1,000 feet from outlet, .	2 : 45	Surface,	.0620	.0380	1,680
" 3, . .	1,000 feet from outlet, .	2 : 45	2 feet, .	.0416	.0312	1,662
" 4, . .	3,400 feet from outlet, .	2 : 55	Surface,	.0132	.0150	1,702
" 4, . .	3,400 feet from outlet, .	2 : 55	2 feet, .	.0206	.0188	1,696

The samples collected on October 24 were taken on the incoming tide. Sewage was being discharged on this day at the rate of about 48,000,000 gallons per twenty-four hours. Low tide was at 11 : 53 A.M. Samples were taken and the area was outlined when the tide was coming over the bar connecting Deer Island and Deer Island Light, and the sewage was flowing towards Governor's Island. A sample taken directly over the outlet, at 1 : 50 P M., contained .98 parts of albuminoid ammonia per 100,000 parts. Samples were collected at 2 : 35 P.M., in the middle of the sewage field, which was then 500 feet from the outlet. The surface sample contained about 20 per cent. as much organic matter as the sample taken over the outlet. At 2 : 45 P.M. samples were collected on the same line, 1,000 feet from the outlet. The surface sample contained only about 4 per cent. as much organic matter as the sample taken directly over the outlet, and the sample from a depth of 2 feet contained still less. Samples were collected at 2 : 55 P.M., at what appeared to be the limit of the area, about 3,000 feet from the outlet. The surface sample at this point was found to be practically normal harbor water. The one from a depth of 2 feet contained slightly more organic matter than the surface sample. The limits of the area of plainly marked sewage pollution upon this day was about 175 acres.

Respectfully submitted,

H. W. CLARK.

L.A.
M39S

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